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LINE BLANKETING IN VEGA AND SIRIUS

Grant NSG 5030

Final Report

Principal Investigator
Dr. Robert L. Kurucz

Prepared for
National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

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Cambridge, Massachusetts 02138

The Smithsonian Astrophysical Observatory
and the Harvard College Observatory
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The NASA Technical Officer for this grant is Dr. James E. Kupperian, Code 410,
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ABSTRACT

Our theoretical model and spectrum calculation for Vega seem to be realistic once we have corrected a few errors in the Kurucz and Peytremann line list. The abundance of carbon is approximately -3.8, which is 0.3 lower than the old solar value and supports Mount and Linsky's newer value. The oxygen abundance is approximately -3.5. Assuming that Vega has solar abundances, the solar oxygen abundance appears to have been overestimated by 0.3 in the log. Other abundances appear to be solar.

For Sirius the calculations do not agree with the observed spectrum. Line opacity is considerably underestimated, notably in third-spectrum iron group lines. Carbon is underabundant relative to Vega by 0.2 in the log. Nitrogen is unchanged. Oxygen is enhanced by 0.3. Heavier elements are enhanced by 1.0 in the log.

Our tentative calibration yields $1.3\text{E}-10 \text{ ergs/cm}^2/\text{s/nm}$ for each U1 Copernicus count at 130 nm.

LINE BLANKETING IN VEGA AND SIRIUS

Final Report

1. INTRODUCTION

Vega and Sirius are two of the brightest, best observed stars. Vega is the archetypical "normal" star that we would expect to have solar or, because it was formed more recently than the sun, slightly enhanced solar abundances. Its angular diameter and distance are known and it does not suffer from theoretical problems such as convection, so one should be able to calculate realistic theoretical models and spectra. For any model atmosphere program or spectral calculation program to be considered accurate and realistic it must reproduce, at least in a general way, the spectrum and energy distribution of Vega. Furthermore, because photometric systems ultimately are defined relative to Vega, theoretical interpretation of photometry depends on the calculation of a model for Vega.

Once theoretical programs are available to treat normal stars, simple parameter changes should allow the prediction of models for evolved stars and stars of different populations. Sirius is a moderately metallic line star, a binary with a white dwarf companion that presumably transferred matter enriched in heavy elements to Sirius A. The mass, diameter, and distance are known for Sirius, and, because it is easily observed at high resolution, it makes a good test case for checking the effects of abundance changes.

With theoretical programs for computing models and spectra, we are investigating Vega and Sirius over the whole spectral range both to determine the properties of the stars themselves and to test the programs. Copernicus provides a unique opportunity to obtain spectra that show strong resonance lines of many elements and many other lines formed through a range of levels in the atmosphere. Such spectra present a strong test of the stellar atmosphere theory.

2. COPERNICUS OBSERVATIONS

Copernicus U1 scans of Vega and Sirius were made during September and November 1974 covering the region 130 to 135 nm with a resolution of approximately 0.0037 nm. We went to Princeton in December 1974 to collect the data.

In Figure 1 we show the scans for both stars normalized as discussed in Section 10. The individual data points for Vega are visible in Figure 8 and for Sirius in Figure 9. Since full scale at 130 nm corresponds to 2400 counts for Sirius and only 575 for Vega, the Vega scan is considerably noisier. The scans were made in small overlapping sections but one piece at 132.9 was not observed in Sirius. The Sirius wavelengths have been incremented by 0.003 nm to align the two spectra approximately, but no other effort has been made to process the data. Wavelengths should be considered uncertain by at least this amount. Although the noise causes some uncertainty, it appears that the same features appear in both spectra, that the stronger features are of similar strength in both stars (e.g., O I at 130.2 and C I at 132.9), but that many features weak in Vega are tremendously increased in Sirius.

3. MODEL ATMOSPHERE FOR VEGA

Observations are available for Vega in the visible that allow a reasonably accurate determination of model parameters. A good fit in the visible is important to this analysis because the far ultraviolet falls on the exponential side of the Planck maximum and, thus, is sensitive to small temperature changes. Conversely, the far ultraviolet continuum and line spectrum provide strong tests of the models because they are so sensitive.

We have computed a grid of model atmospheres that include line opacity in the form of statistical distribution functions (Kurucz, in preparation). By comparing these models to the energy distribution determined by Hayes and Latham (1975) we determined parameters $T_{\text{eff}} = 9400 \pm 200 \text{ K}$ and $\log g = 4.0 \pm 0.5$. Then, with Deane Peterson at Stony Brook, we programmed the Vidal, Cooper, Smith theory (Vidal, Cooper, and Smith, 1973) for hydrogen line profiles. By comparing to Peterson's (1969) Balmer line profiles we determined $\log g = 3.95 \pm 0.05$. These parameters are consistent with Code's (1975) empirical values, 9660 ± 130 , and 3.94 ± 0.08 . Figures 2 and 3 show the comparisons between the observations and a 9400, 3.95 model. There is a small discrepancy in that the Balmer line cores are narrower than those observed. As discussed in Section 7, Vega has a projected rotational velocity of approximately 25 km/s. Rotationally broadening the theoretical profile would widen the core to match but would leave the central residual intensity too high. Non-LTE effects, which have not been included, presumably would lower the central intensity (Peterson, 1969).

This model was computed assuming solar abundances from Withbroe's compilation (1971). Thus we assumed -3.48 for the log carbon abundance relative to the total. However, as discussed in Section 9, the actual carbon abundance is nearer -3.8. Since the carbon continua are important features in the far ultraviolet, the abundance change reduces the total ultraviolet opacity and decreases the backwarming. This may mean that a slightly hotter model with the new abundances may be more correct. We have not yet determined the magnitude of such a correction.

4. MODEL ATMOSPHERE FOR SIRIUS

In the grid calculation described above, it is a simple matter to compute models at scaled solar abundances, but it is expensive to make changes that require recomputing line opacity. As a moderately metallic line star, Sirius has decidedly nonscaled abundances, with light elements near solar and with metals overabundant by a factor of 10 or so (Kohl, 1964; Latham, 1970). As a first step we tried the approximation of a 10,000,4.3 model with all abundances increased by 0.5 in the log. These parameters are approximately Code's (1975), 9975 ± 150 and 4.31 ± 0.04 . This model agrees fairly well with Peterson's (1969) Balmer line profiles and with the energy distribution given by Latham (1970), corrected to the new calibration of Vega by Hayes and Latham (1975). It would be useful to have new, improved observations of the energy distribution of Sirius.

The initial spectrum calculation with abundances increased by 0.5 in the log was grossly inconsistent with the observations. We were able to improve the fit by changing abundances of various elements. Then we computed a model with abundances C -4.00, N -4.00, O -3.22, and heavier elements 10 times solar, but with line opacity tables computed for abundances 10 times solar. Thus the model is not consistent. We are currently using this model in the spectrum calculations; but, as discussed in Section 9, there remain inconsistencies in the spectrum indicating that the model may need improvement.

5. SPECTRUM SYNTHESIS PROGRAM

We have continually improved our spectrum synthesis program during the course of this research. The basic program works as follows. For a given model atmosphere tabulated at 40 depths, we compute number densities and partition functions for all atoms and ions. Then we read the magnetic tape that lists the gf values calculated by Kurucz and Peytremann (1975, hereinafter called KP) and compute a line opacity spectrum at each depth. The expressions for radiative, Stark, and van der Waals broadening are

$$\Gamma_R = \Gamma_{\text{classical}} = 2.223 \text{E}13 / \lambda^2, \quad \lambda \text{ wavelength in nm} ;$$

$$\Gamma_S = 1.0 \text{E}-8 n_{\text{eff}}^5 N_e ;$$

$$\Gamma_W = 4.5 \text{E}-9 \langle r^2 \rangle^{4/10} [N_H + 0.42 N_{\text{He}} + 0.85 N_{\text{H}_2}] (T/10,000)^{3/10} ;$$

where

$$\langle r^2 \rangle = 2.5 n_{\text{eff}}^2 / Z_{\text{eff}}^2 ,$$

$$n_{\text{eff}}^2 = R Z_{\text{eff}}^2 / E_{\text{up}} ,$$

Z_{eff} is the charge plus 1, E_{up} is the upper level energy, and R is the Rydberg energy. Next, continuum quantities, opacities, source functions, and fluxes, are evaluated at several points in the wavelength interval. Then, the continuum quantities are interpolated to each point in the spectrum, the line opacity added, the source function approximated by

$$[(\kappa + \sigma) S_{\text{cont}} + \ell S_{\text{line}}] / (\kappa + \sigma + \ell) ,$$

and the surface flux or intensity computed. Here κ and σ are the continuous absorption and scattering coefficients, ℓ is the line absorption coefficient, S_{cont} is the continuum source function, and S_{line} is the line source function, which is assumed to be the Planck function.

The following improvements have been made. We have computed mean square radii for the 4p orbitals of the iron group atoms and ions, and produced an interpolation formula

$$\langle r^2 \rangle = (45 - A + Z)/(Z + 1) \quad ,$$

where A is the atomic number and Z is the charge. This expression is used for van der Waals broadening of all iron group atoms, assuming that the strong lines are all resonance lines with a 4p upper state.

There is now provision for additions, deletions, and corrections to the table of gf values and for use of individual "real" radiative, Stark, and van der Waals damping constants for each line.

To resolve the contribution of individual lines to blends, we now compute, in addition to the spectrum, the central intensity for each line in isolation.

We automatically produce spectrum plots with identifications.

6. ROTATIONAL BROADENING OF THE THEORETICAL SPECTRUM

In practice, most spectra must be rotationally broadened to compare with observations. We have developed a broadening procedure of direct numerical integration over the stellar disk. This procedure is simple and easily generalized to treat gravity darkening, nonuniform rotation, nonspherical stars, and binaries. In the simple case of uniform rotation, no gravity darkening, and circular projection, we can use symmetry to reduce the evaluation to one quadrant.

The integration is performed by laying a grid of any fineness over the stellar disk and simply adding the intensity at each point. For the calculations reported here we used a spacing of 0.02 times the radius. At each point on the grid we compute the doppler shift and the cosine of the angle of projection. The doppler shift is converted to an integral number of steps in the spectrum (multiples of the point spacing) and the cosine is converted to an integral multiple of 0.01. In general there will be grid points on the disk that have the same values of these integers. All the values are sorted and the multiplicity of each is noted. The multiplicities are added and a normalization factor is determined such that integration of I_ν produces H_ν . This set of numbers is the rotation operator.

For the work described here we computed the spectrum with a spacing of 0.5 pm at 17 angles and interpolated to 100 cosines from 0.005 to 0.995. These spacings were chosen arbitrarily. Smaller spacings might improve the accuracy of the final spectrum. Fewer angles than 17 are possible. We should point out that computation time is not proportional to the number of angles since the opacity spectrum need be computed only once for any number of angles.

To broaden the spectrum rotationally, we read the intensities $I_{j\mu}$ one wavelength at a time and distribute each intensity into a flux spectrum H using the rotation operator. For example, if part of the operator is an 11-step doppler shift for a cosine index μ of 37 with a multiplicity of 4, we would add $4I_{j37}$ to H_{j+11} and, by

symmetry, to H_{j-11} . Thus we go through every term of the operator for every wavelength in the spectrum. Once the totals are completed we normalize. If the doppler width of the operator includes many steps, N , the accuracy is improved by filtering with a $(1 + N/5)$ -step straight mean. The accuracy of this procedure is better than 1 percent for computing flux from intensity at zero rotation velocity, for the parameters quoted. The accuracy can be improved to any desired limit by increasing the resolution.

7. ROTATION OF VEGA AND SIRIUS

These stars have quite significant projected rotational velocities that blend the lines and greatly complicate the analysis. We have been collaborating with Ingemar Furenlid at Kitt Peak and with John Lester at SAO to obtain high-resolution, low-noise spectra in the visible. Through visual examination of 1 Å/nm plates taken by Furenlid, we estimate velocities of 15 to 20 km/s for Sirius and 25 to 30 km/s for Vega. These spectra have not yet been reduced so we have assumed velocities of 15 and 25 km/s in our calculations thus far. The zero velocity and rotationally broadened spectrum for Vega is shown in Figure 4 and for Sirius in Figure 5. The observed Copernicus spectra suggest a velocity somewhat larger than 15 km/s for Sirius and seem consistent with 25 km/s for Vega.

We have also undertaken a project with Wesley Traub, Nathaniel Carleton, and John Lester of SAO to measure a Ba II line profile in Sirius with a high-resolution interferometer. Since the project was begun before we found that Sirius has a high rotation velocity, we had hoped to determine both a rotation velocity and a maximum turbulent velocity. The reductions have not yet been completed, but we provisionally find a rotation velocity of 17 km/s.

8. THEORETICAL LINE LIST

One of the aims of this research is to check the available line data for accuracy and completeness and to identify areas where further work is required. Our basic source of these data is the KP line list, which was computed, for sequences up through nickel, by using scaled Thomas-Fermi-Dirac wavefunctions and eigenvectors found through least-squares fits of eigenvalues to observed levels (Kurucz, 1973). Heavier elements and the lightest elements were taken from the literature. The data published by KP represent only a fraction of the lines calculated, those between known levels. There are many lines between predicted levels that cannot be used for spectrum synthesis because the wavelengths are uncertain, but which can be used in computing the statistical distribution functions for the model atmosphere calculations.

We emphasize that spectroscopic analyses of many elements leave considerable room for improvement. There are levels that have not been classified, and so cannot be included in a gf calculation, and there are levels that are misclassified. Most important, many analyses are highly incomplete. Several of the iron group second spectra have not even been observed in the vacuum ultraviolet. We expect such lines account for a number of unidentified features in the Copernicus spectra.

Through examination of Kelly and Palumbo's (1973) line list and the ultraviolet multiplet table (Moore, 1962) we have found one prominent example of the incompleteness of KP. Multiplet 56 of Mn II is not in the list because the upper term has not been classified and so could not be computed. Kelly and Palumbo list a number of weak lines that have not been classified and do not appear in KP.

Thus far we have identified two sorts of errors in the KP line list through the presence of identifiable observed lines where the line list predicts none, and through the presence of a prominent predicted feature where none is observed. Several C II, N III, and Si II transitions involving sp^2 , and several O I, Si II, and S I transitions involving an excited parent, are missing, presumably through programing mistakes. These errors may also occur in other elements that have not yet been checked.

Fortunately, these strong lines appear in the NBS compilations (Wiese, Smith, and Glennon, 1966; Wiese, Smith, and Miles, 1969; Wiese and Glennon, 1972). We have also found a few excited, LS forbidden, C I and N I lines that are computed too strong. Apparently the eigenvector mixing was overestimated.

In general, we assume that laboratory gf values based upon lifetime measurements are more reliable than KP. We are undertaking to replace KP data with such data, especially from the NBS compilations. However, we expect KP to be more accurate than NBS coulomb approximation f values and to give better relative strengths within multiplets than NBS LS multiplets.

We are also undertaking to include radiative and Stark damping constants for the stronger lines. At the present time we are filling in transition arrays and summing A's by hand to get the radiative damping constants. Programs are under development that will produce the radiative damping constants for every transition of an element. The sources used thus far for Stark broadening are Sahal-Brechot and Segre (1971) and Griem (1974). To use Griem's widths we compute

$$\Gamma_s/N_e = 3767 W/\lambda^2$$

with width W at 10,000 or 20,000 K and wavelength λ in Å. We have not yet included all Griem's data.

We expect to publish, either as part of this work, or as a separate publication, tables of these revisions.

9. COMPARISON OF THE SPECTRA

Figures 6 and 7 show the current theoretical and observed spectra for Vega and Sirius normalized as discussed in Section 10. Figures 8 and 9 are the same plots with identifications for all theoretical lines with zero rotation residual fluxes less than 0.99 in Vega and 0.98 in Sirius. In calculating the spectra the 9400, 3.95 and 10,000, 4.3 models described in Sections 3 and 4 were used. In Vega the carbon abundance was reduced from -3.48 to -3.8. A microturbulent velocity of 2 km/s was assumed for the time being.

Since improvements and corrections to the program and line data are an ongoing process, the current plots are the result of a long series of iterations. Except for the abundance changes described in Sections 3 and 4 and below, no attempts have been made to adjust individual lines for a match. The fit is remarkably good for Vega. For Sirius a number of lines match very well but the majority of the lines are grossly underestimated in the calculations. No fourth spectrum or higher lines appear in either the calculations or the observations. In the discussion of individual elements below we assume that the gf values and damping constants are correct. (We use the terms weak and strong to refer to the comparison, calculation relative to observation, not to the strengths of the lines.)

Hydrogen. There is background Lyman α wing but the Vega data are too noisy and the match in Sirius is not good enough to draw any conclusions at this time.

Helium, Lithium, Beryllium, Boron. There are no lines in this spectral region.

Carbon. The C I resonance lines at 132.9 are computed too strong in Vega but match well in Sirius. The lines around 131.1 from the 1D lower level are blended in features that are calculated too weak. The continuum in this region arises from the 1S level. The C II resonance lines at 133.5 are computed with approximately correct cores. The wings are not right in Vega but there may be lines present in

the noise. A C III line at 130.870 does not appear in the spectra. Since C is mainly C II we would expect the C II lines to be more reliable abundance indicators, and the C I lines to be much more sensitive to atmospheric variations. For abundances other than -3.8 in Vega and -4.0 in Sirius the C II lines are discrepant.

Through personal conversations with M. A. J. Snijders of Goddard, we found that his non-LTE calculations predict increased ionization of C I in Vega and LTE in Sirius. Thus the C I lines would become weaker in Vega without significantly changing the C II lines. The strength of the continuum would also be reduced.

Since we expect Vega to have solar abundances, the solar abundance of C may be overestimated by a factor of 2. Such a result has been found by Mount and Linsky (1975) through analysis of solar molecular features. Sirius is depleted in C by 0.2 in the log relative to Vega.

Nitrogen. There is an isolated N I doublet at 131.967 that is a good match. The blended features at 131.89 and 130.00 are difficult to interpret. N II lines at 134.3, 134.5, and 134.6 do not appear in the predicted spectra, but there are features in the observed spectra. N III lines do not appear. The N abundance is equal and approximately solar in both stars.

Oxygen. The O I resonance lines at 130.2, 130.4, and 130.6 are predicted too strong in Vega and approximately correct in Sirius. We have not yet determined the O abundance in Vega but we guess -3.5. Since we expect Vega to have solar abundances, we suggest that the solar abundance should be -3.5 instead of -3.22, which is currently assumed. In Sirius the abundance is approximately -3.22, a factor of 2 enhanced over Vega.

Fluorine. There are no F I lines in this region. The high excitation F II lines at 132.7, 132.8, 133.2, 133.3, 134.3, and 134.4 do not appear in the calculations, however, in some cases, observed features do correspond. The same situation applies to F III. We can say nothing about the F abundance.

Neon. There are no Ne lines in this region.

Sodium. There are no Na I lines in this region. Na II and III lines do not appear in either spectrum.

Magnesium. There are no Mg I lines in this region. In Vega, the Mg II lines match at 130.67 and 130.82, are too strong at 130.78, and are blended at 130.94. In Sirius, 130.67 matches while 130.78 and 130.82 are slightly strong. Mg III lines do not appear. The Mg abundance is approximately solar in Vega and +1.0 in Sirius.

Aluminum. There are no Al lines in this region.

Silicon. There are no Si I lines in this region.

Si II: 130.08 weak
130.43 blend, strong
130.56 blend, good
130.9 blend, good
134.68 Vega, slightly strong; Sirius, strong
134.85 Vega, slightly strong; Sirius, strong
135.0 strong

Si III: 130.11 slightly strong
130.33 blend, strong
131.25 weak?
134.24 blend
134.33 blend

The Si abundance in Vega is approximately solar and in Sirius at least +1.0. The models predict the correct ionization.

Phosphorus. The P I line at 130.447 is blended. P II lines at 130.18, 130.46, 130.54, 130.98, and 131.07 are blended in such a way that one can tell the lines are approximately the right strength. Of the P III lines, 133.48 is blended and, in Sirius, blended and strong, 134.43 is blended and strong, 134.49 possibly matches. The wavelengths are discrepant. Other lines do not appear in either star. The P abundance is approximately solar in Vega and +1.0 in Sirius. The models predict the correct ionization.

Sulfur.

S I:	130.23 blend	131.32 blend, good
	130.28 blend, slightly strong	131.65 slightly strong
	130.31 blend, slightly strong	132.35 slightly strong
	130.34 blend, slightly strong	132.66 blend, slightly strong
	130.58 blend, good	133.37 blend, strong
	131.01 blend, good	

There are no S II lines in this region. S III lines do not appear in the spectra. The sulfur abundance is approximately solar in Vega and +1.0 in Sirius.

Chlorine. The Cl I line at 133.57 is blended. The line at 134.72 is slightly weak. There are no Cl II or III lines in this region. The Cl abundance is approximately solar in Vega and +1.0 in Sirius.

Argon. There are no Ar I lines in this region. There is an Ar II line at 134.72 that does not appear in the predicted spectrum for Vega but does weakly in the predicted spectrum for Sirius. There is an observed feature in both stars at this wavelength that is stronger in Sirius. These lines are highly excited and would be very sensitive to temperature changes. There are no Ar III lines in this region. We can draw no conclusions about the abundance of Ar.

Potassium. There are no K lines in this region.

Calcium. There are no Ca I lines in this region.

Ca II:	130.56 masked
	132.98 blended, strong in both stars
	133.09 match in both
	134.18 slightly weak in both
	134.25 blend, slightly weak in Vega, matches in Sirius

Ca III lines do not appear in the predicted spectra. There is an unidentified feature at 133.74, which is the wavelength of one of the lines. The Ca abundance is approximately solar in Vega and +1.0 in Sirius.

Scandium. There are no Sc I or III lines in this region. Sc II lines have not yet been observed in this region.

Titanium. There are no Ti I lines in this region. Ti II lines have not yet been observed in this region. Ti III 132.75 matches in both stars, 132.98 is blended, and 133.96 is noisy in Vega and matches in Sirius. The Ti abundance is approximately solar in Vega and +1.0 in Sirius.

Vanadium. There are no V I lines in this region. There are six V II lines that are masked, blended, or insignificant. A feature is observed in Sirius at 131.38, but the calculated feature is much weaker. There are a dozen V III lines but they are all masked, blended, or insignificant. We can say nothing about the V abundance.

Chromium. There is no Cr I in this region. Cr II has not yet been observed. The relative strengths of Cr III lines are the same in both stars but many of the lines are very noisy in Vega.

Cr III: 131.15 blended, masked	132.16 blend, weak
131.40 very weak	132.28 weak
131.54 masked	132.84 very weak
131.64 blend, slightly strong	133.15 blend, weak
132.00 very weak	133.77 weak

Either Cr has a greatly enhanced abundance or there is some error in the models that produces the wrong ionization for Cr III.

Manganese. There are no Mn I lines in this region.

Mn II: 130.10 blend, strong in both stars
130.67 blend
133.15 blend, weak
134.43 blend, strong
134.56 weak

The gf values for multiplet 56 could not be computed by KP but the lines are present in the observed spectra,

130.56 masked
131.34 masked
131.37 present in both stars, stronger in Sirius
131.73 may be present in blend
131.77 present in Sirius, not apparent in Vega
131.80 present in both stars, stronger in Sirius.

The Mn III line at 134.76 is very weak. We can draw no conclusions about the Mn abundance.

Iron. There are no Fe I lines in this region. There are numerous Fe II and Fe III lines. We get the impression that many features observed in Sirius correspond to Fe III lines that are weak in the calculated spectrum. It is possible that this is a coincidence because there are so many lines. In Vega, the noisiness and questions about the normalization level make the comparison difficult for many of the weaker features. In Vega there are a number of Fe II lines that seem to match so we guess that the abundance is approximately solar. In Sirius those lines are predicted slightly weak which may indicate an Fe abundance increase greater than 1.0. There seem to be problems with ionization and Boltzman factors.

Cobalt. There are no Co I lines in this region. The Co II lines at 130.69, 131.18, and 131.81 are weak in both stars. Other lines are masked or blended. The Co III line 132.68 is not seen in Vega and is predicted to be insignificant in Sirius. The Co abundance is greater than solar in Vega and greater than +1.0 in Sirius. The solar Co abundance may be underestimated.

Nickel. There are no Ni I lines in this region. There are numerous Ni II lines. The resonance lines at 130.88, 131.72, 133.52, and 134.58 match. Higher excitation lines are weak but correspond to many features. The Ni III lines are weak. There seems to be some ionization problem. If some way could be found to increase the strength of the weak Ni II and III lines the calculated spectra would fit much better.

Copper. There are no Cu I lines in this region. Cu II lines do not appear in Vega. Two lines, 130.39 and 133.18, are predicted as small in Sirius. No Cu III lines appear in any of the spectra.

Zinc. Zn I lines have not been observed in this region. The Zn II line at 130.6741 was not computed by KP but may be present in the observed spectra. All Zn III lines are insignificant or masked.

Elements heavier than the nickel sequence. Heavier elements were not computed by KP and gf values for lines in this region were not available from the literature so the line list does not predict any heavy lines in this region. An examination of Kelly and Palumbo (1973) and Moore (1962) does not produce any obvious identifications. Detailed searches will be made in the future.

Our overall impression is that there is a temperature problem with the models because resonance lines of lighter elements seem to match in all stages of ionization, while highly excited iron group lines are predicted too weak. Further work is required to determine whether temperature increases will resolve the discrepancy. Temperature changes in Vega cannot be very large because of the good fits with the strong lines and in the visible.

10. CALIBRATION OF COPERNICUS IN THE REGION 130 TO 135 nm

We have assumed that the wavelength dependence of the Copernicus sensitivity did not vary in the time between the observations of the two stars so the same relative shape applies to both Sirius and Vega. In plotting the spectra we overlaid the observations on the calculations and determined a relative shape and the number of counts at full scale required to force a match. Currently, the counts are 2400 for Sirius and 575 for Vega at 130 nm. The shape factor that converts from counts to energy is given in this table:

Wavelength	130 nm	131	132	133	134	135
Factor	1	1.0	1.0	1.1	1.1	1.2

The noisiness of the Vega spectrum and the large number of lines in the Sirius spectrum that do not match leave considerable room for subjective fitting. Since there are several places in Vega where the observed spectrum rises above the calculated spectrum, these numbers will probably be revised.

To determine the absolute calibration in $\text{ergs/cm}^2/\text{s/nm}$ per count in U1, we use the angular diameters measured by Hanbury Brown, Davis, and Allen (1974). The flux at the earth is inversely proportional to the square of the distance,

$$\text{flux} = (R_*/D)^2 4\pi H_\lambda = (\theta/2/206265)^2 4\pi H_\lambda ,$$

where θ is the angular diameter of the star in arc seconds. At 130 nm we find

	Sirius	Vega
θ	0.00589 ± 16	0.00324 ± 7 arc sec
H_λ , full scale	$1.320\text{E}8$	$8.842\text{E}7$ ergs/cm ² /s/ster/nm
U1 counts, full scale	2400	575
flux/count	$1.41\text{E}-10$	$1.20\text{E}-10$ ergs/cm ² /s/nm/count

11. FURTHER WORK

We expect to compute one or two more iterations of the Vega spectrum to determine the oxygen abundance and include additional damping constants. We also plan to check for non-LTE effects in C I using b 's computed by Snijders and another spectrum synthesis program that we have developed to do non-LTE spectra. We need to make another iteration on Sirius with the additional damping constants and we will attempt to identify additional features. This additional research and this final report will be submitted to the Astrophysical Journal Supplement.

We will apply for additional observing time on Copernicus to obtain as much of the spectra of the two stars as possible, hopefully with lower noise in Vega. In fact, we believe that observations of Sirius and Vega are so important that Copernicus should be used to produce atlases for the two stars.

Since we are undertaking a detailed analysis of both stars in the visible as well as the ultraviolet, we think that detailed discussion of f values and individual abundances should wait until complementing observations from all spectral regions can be considered together.

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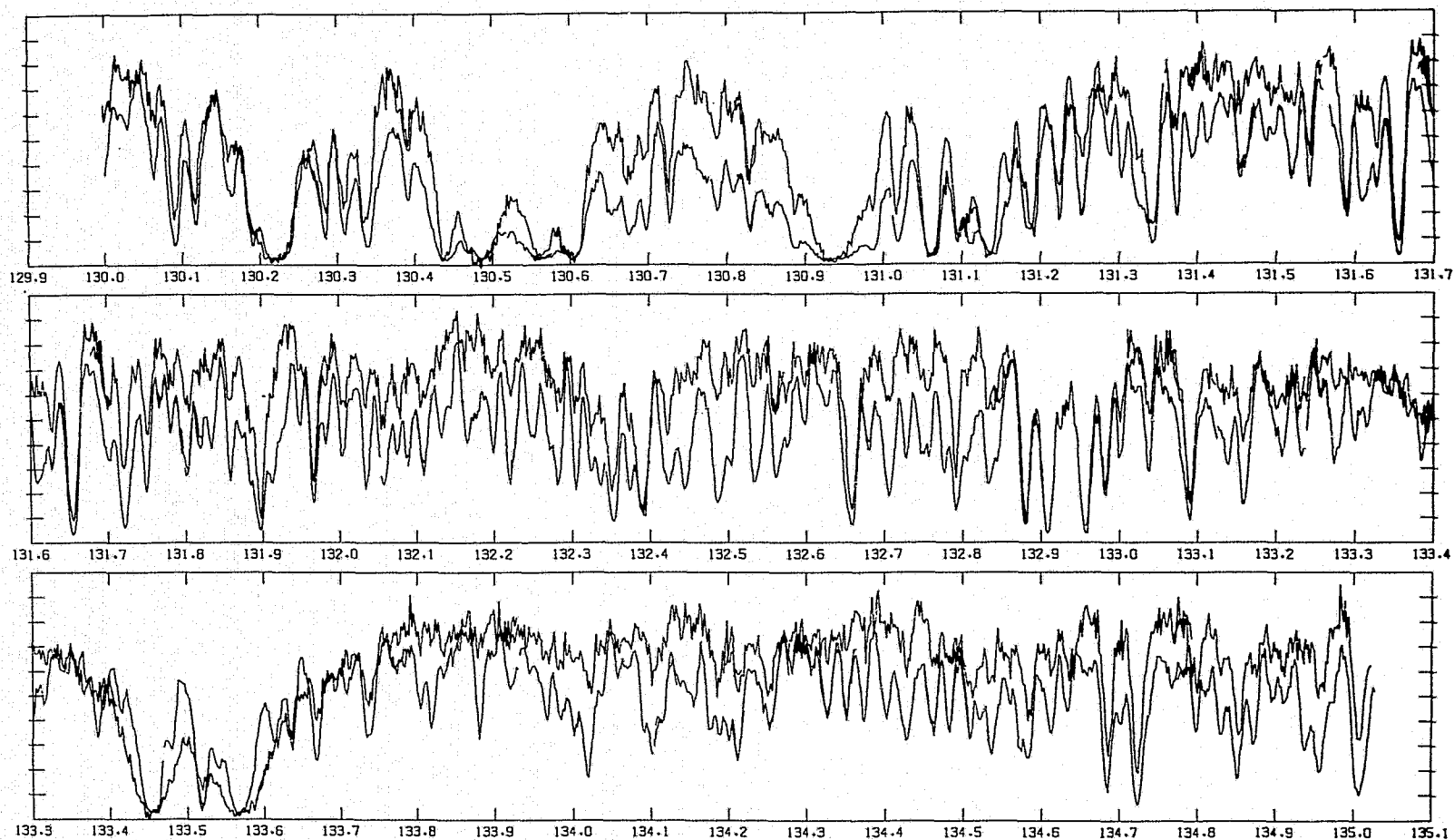


Figure 1. Copernicus UI spectra of Vega and Sirius for the interval 130 to 135 nm. Sirius is the less noisy, generally lower curve. Full scale at 130 nm corresponds to 2400 counts for Sirius and 575 for Vega. Figures 8 and 9 show the individual data points.

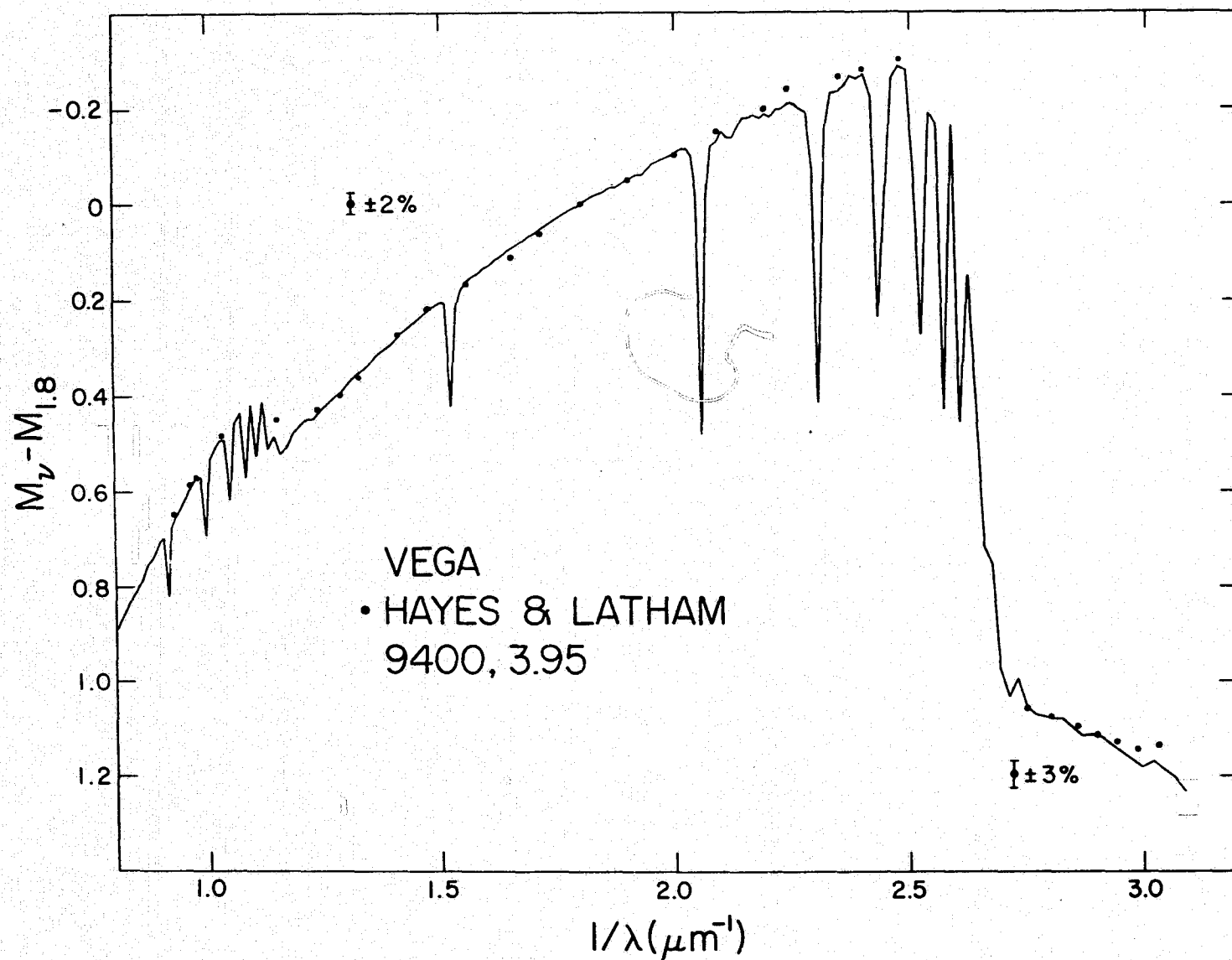


Figure 2. Comparison of the colors of the theoretical model with $T_{\text{eff}} = 9400$, $\log g = 3.95$ with the new Vega observations of Hayes and Latham (1975). Error bars for the observations are indicated.

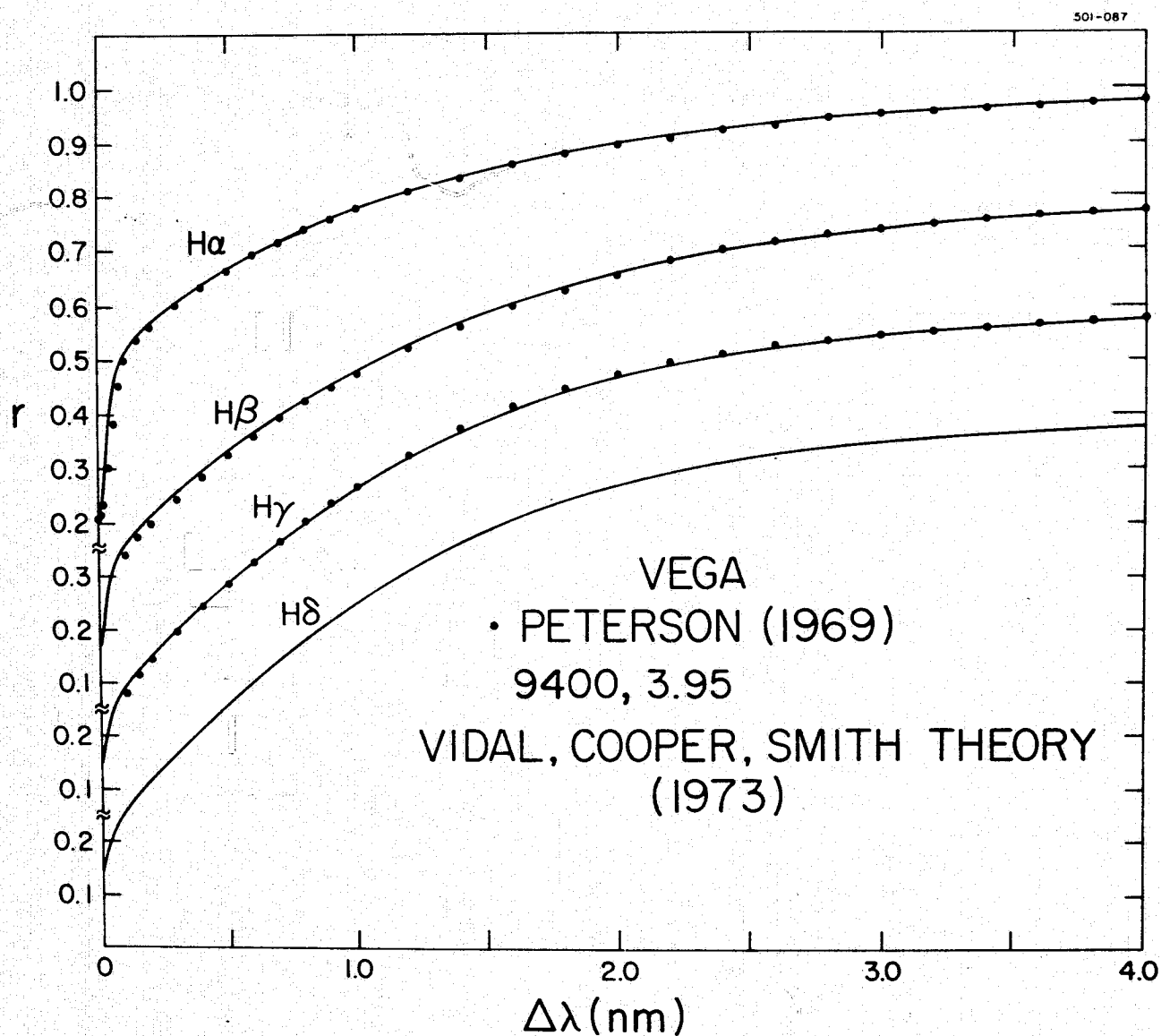


Figure 3. Theoretical Balmer line profiles for the same model compared with the observations of Peterson (1969).

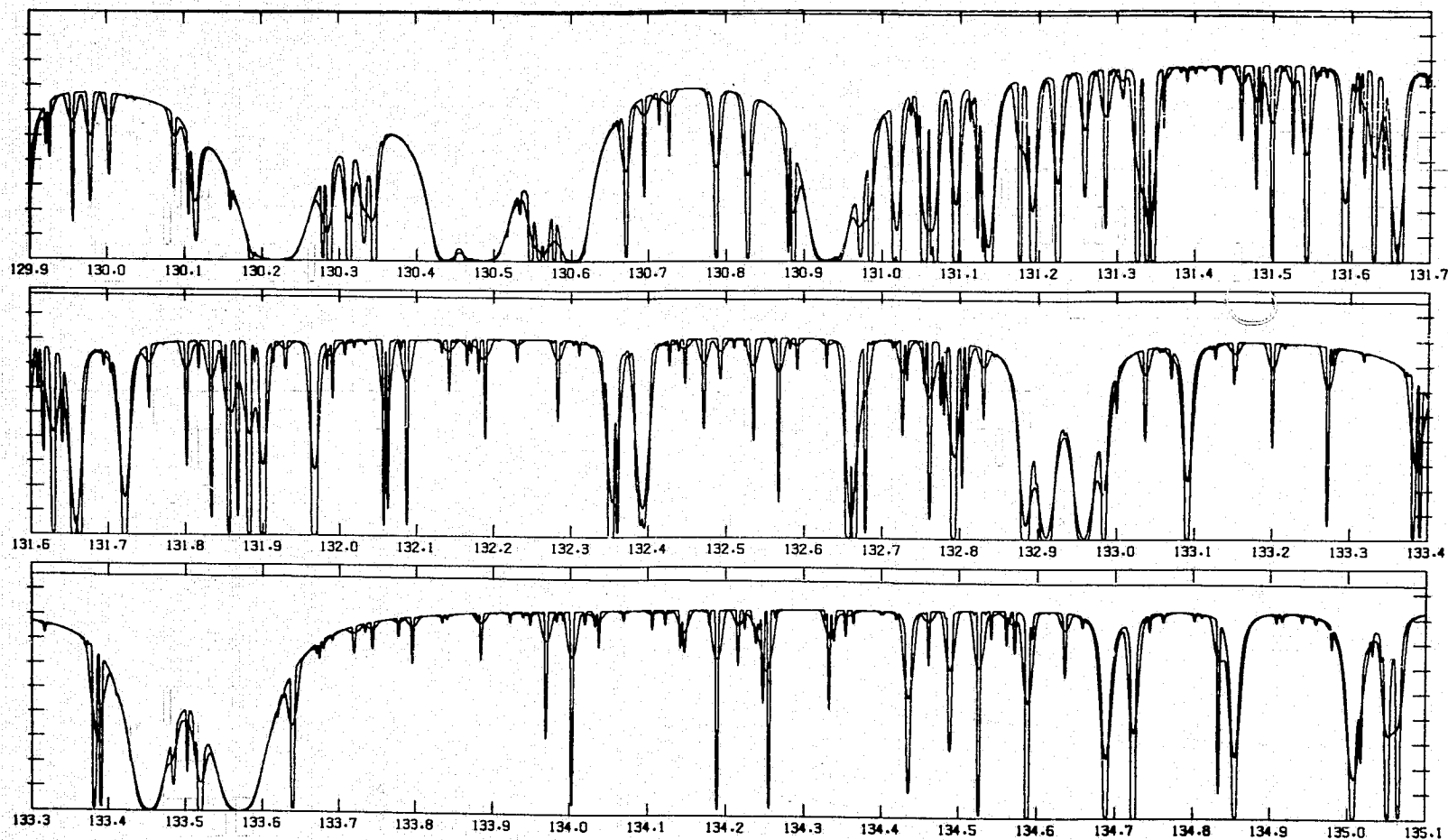


Figure 4. Calculated spectrum for Vega at 0 km/s and rotationally broadened to 25 km/s. The continuum is also shown. Full scale is $8.842 \times 10^7 \text{ ergs/cm}^2/\text{s/ster/nm}$.

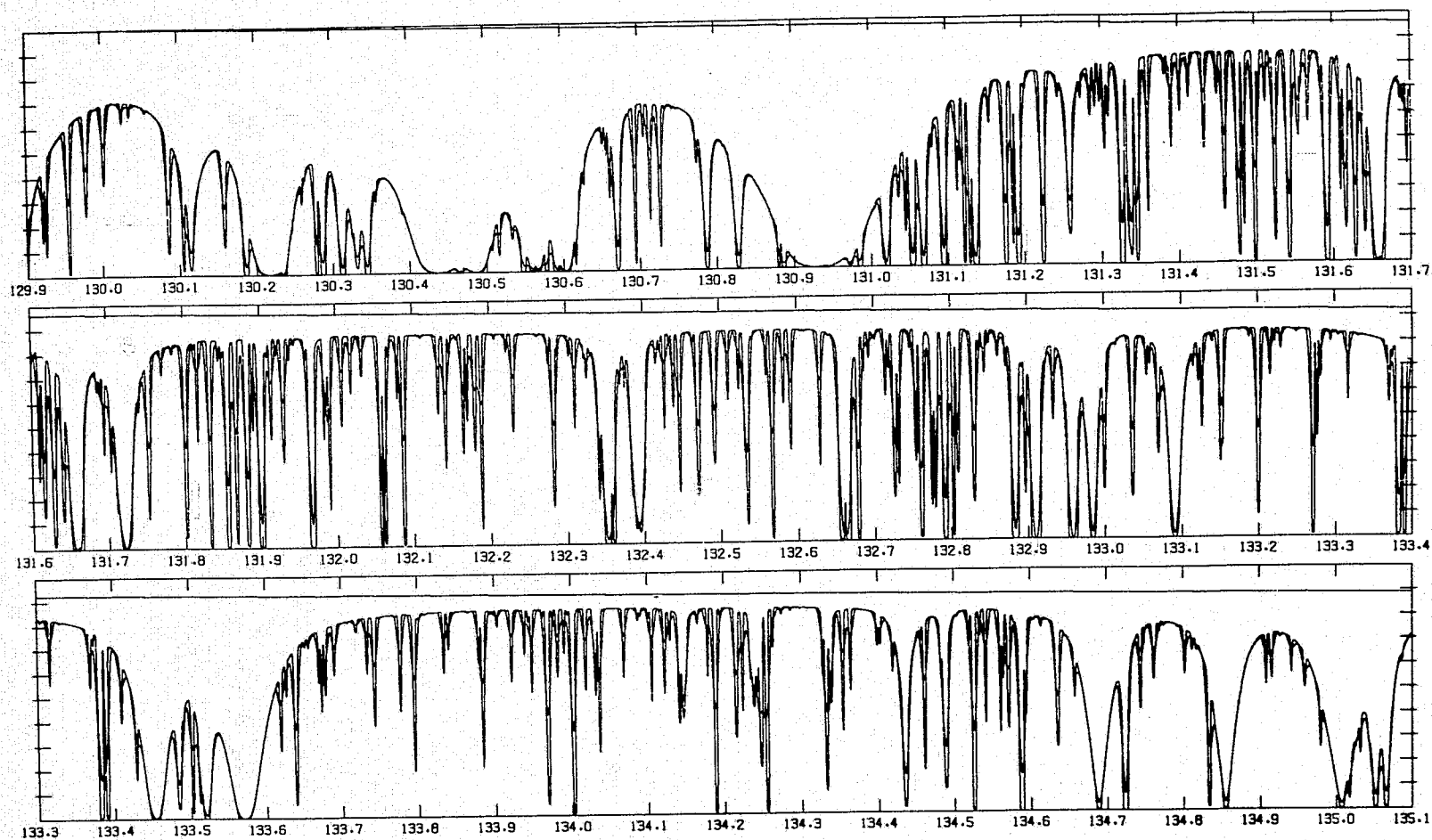


Figure 5. Calculated spectrum for Sirius at 0 km/s and rotationally broadened to 15 km/s. The continuum is also shown. Full scale is 1.320×10^8 ergs/cm²/s/ster/nm.

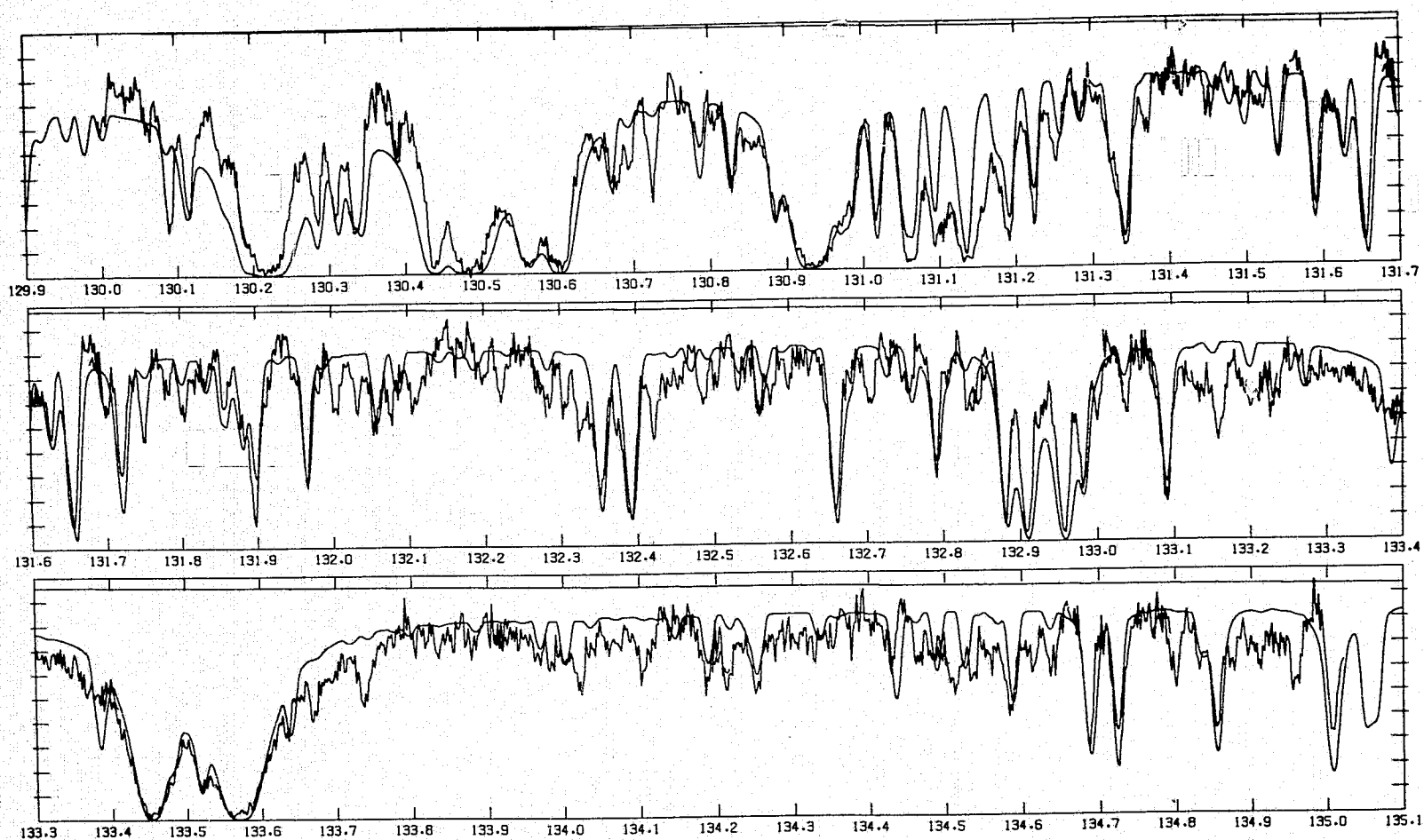


Figure 6. Calculated spectrum for Vega compared to the observations.

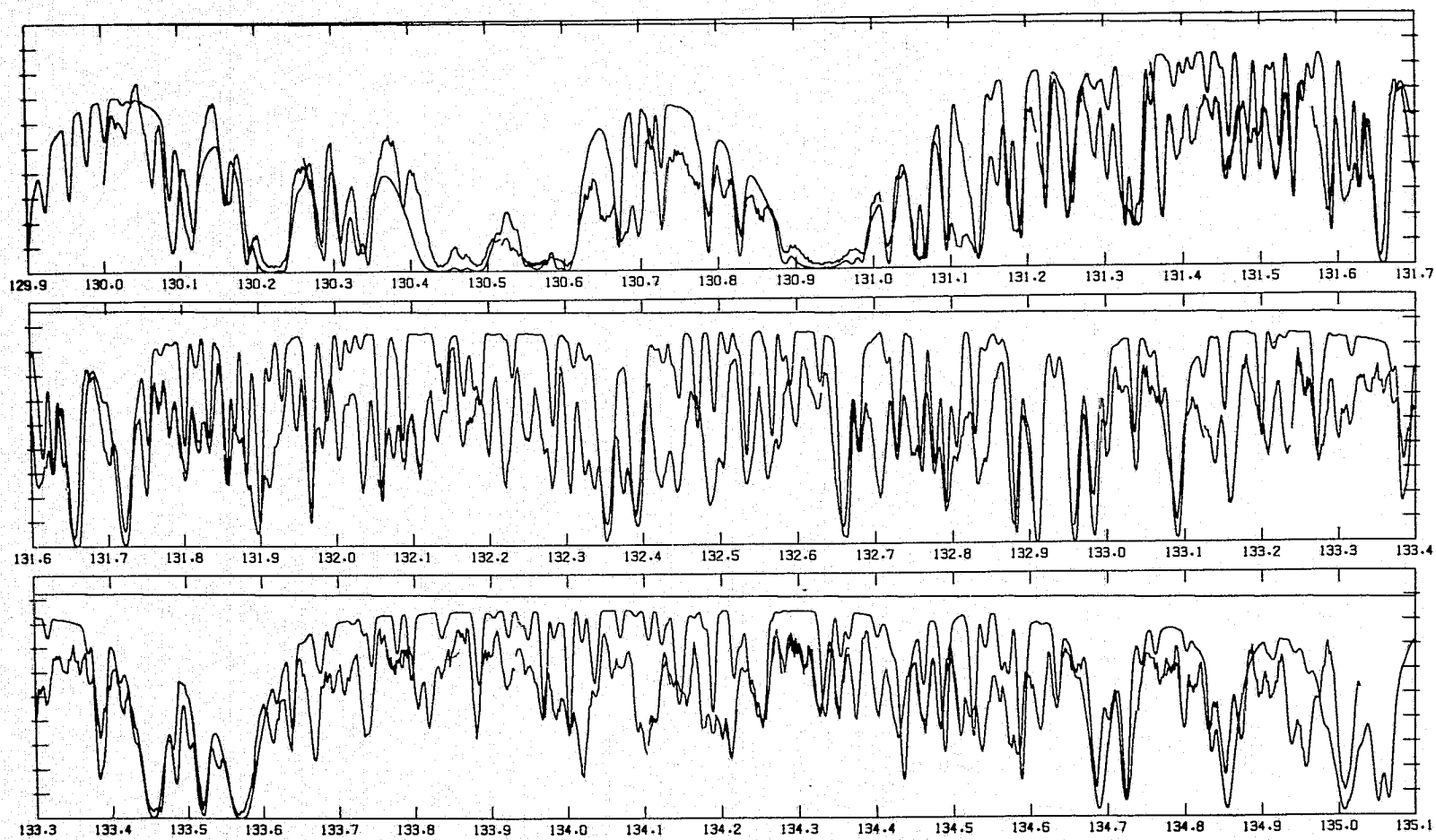
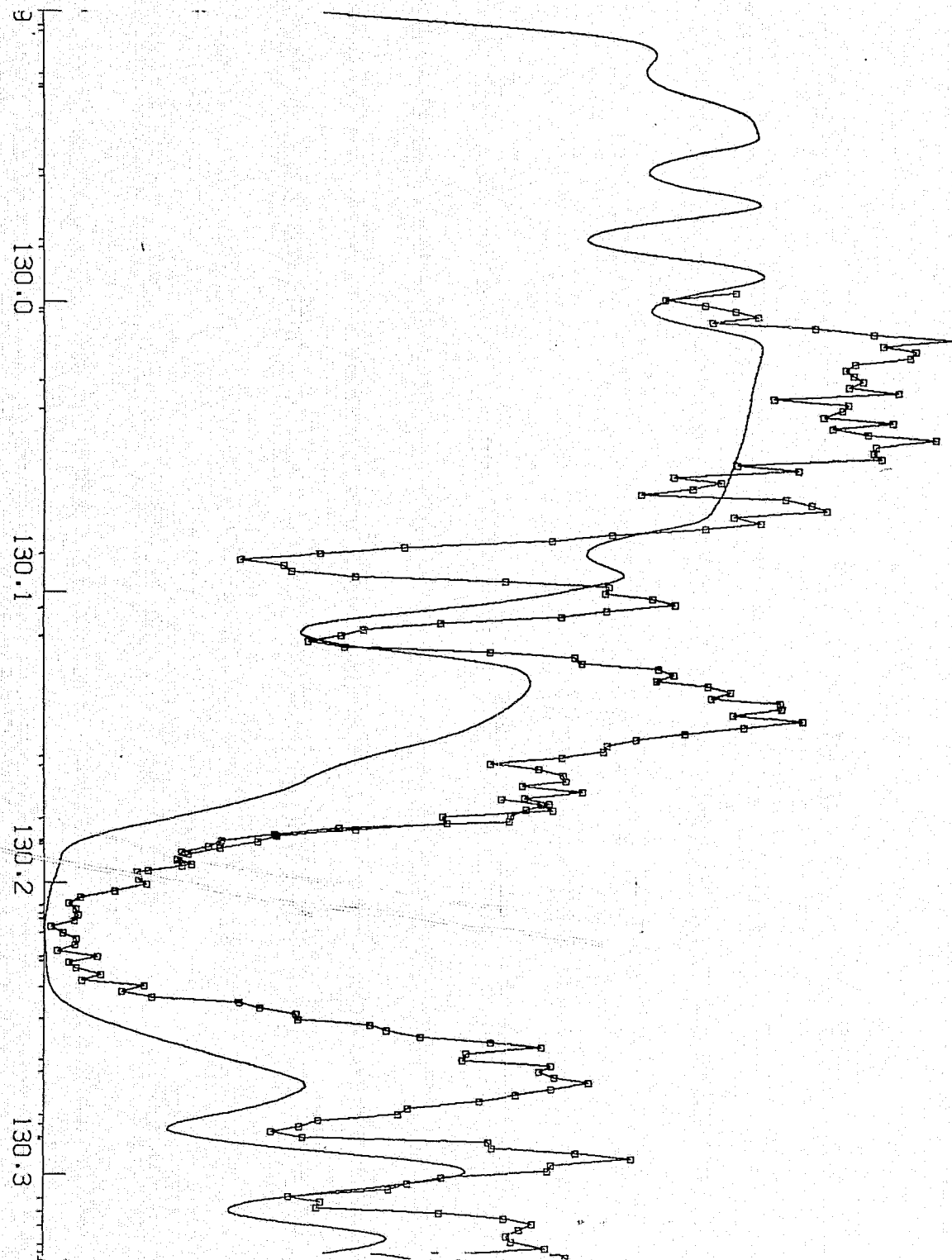


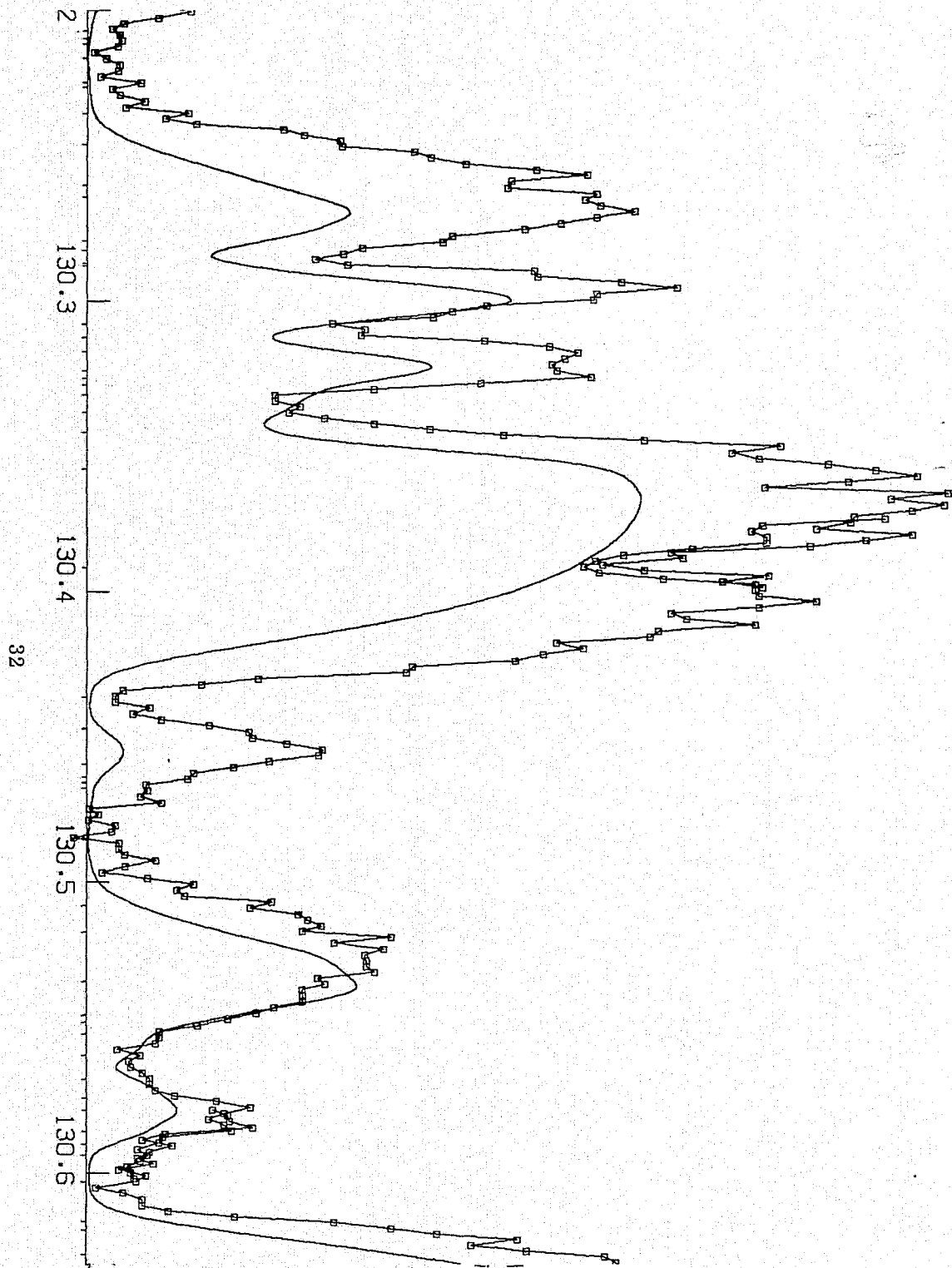
Figure 7. Calculated spectrum for Sirius compared to the observations.

Figure 8. Calculated spectrum for Vega compared to the observations with identifications. The labels consist of the last three digits of the wavelength, the symbol for the ion - atomic number plus charge, lower energy level in cm^{-1} , and the residual flux in per mil at line center in the unrotated spectrum.



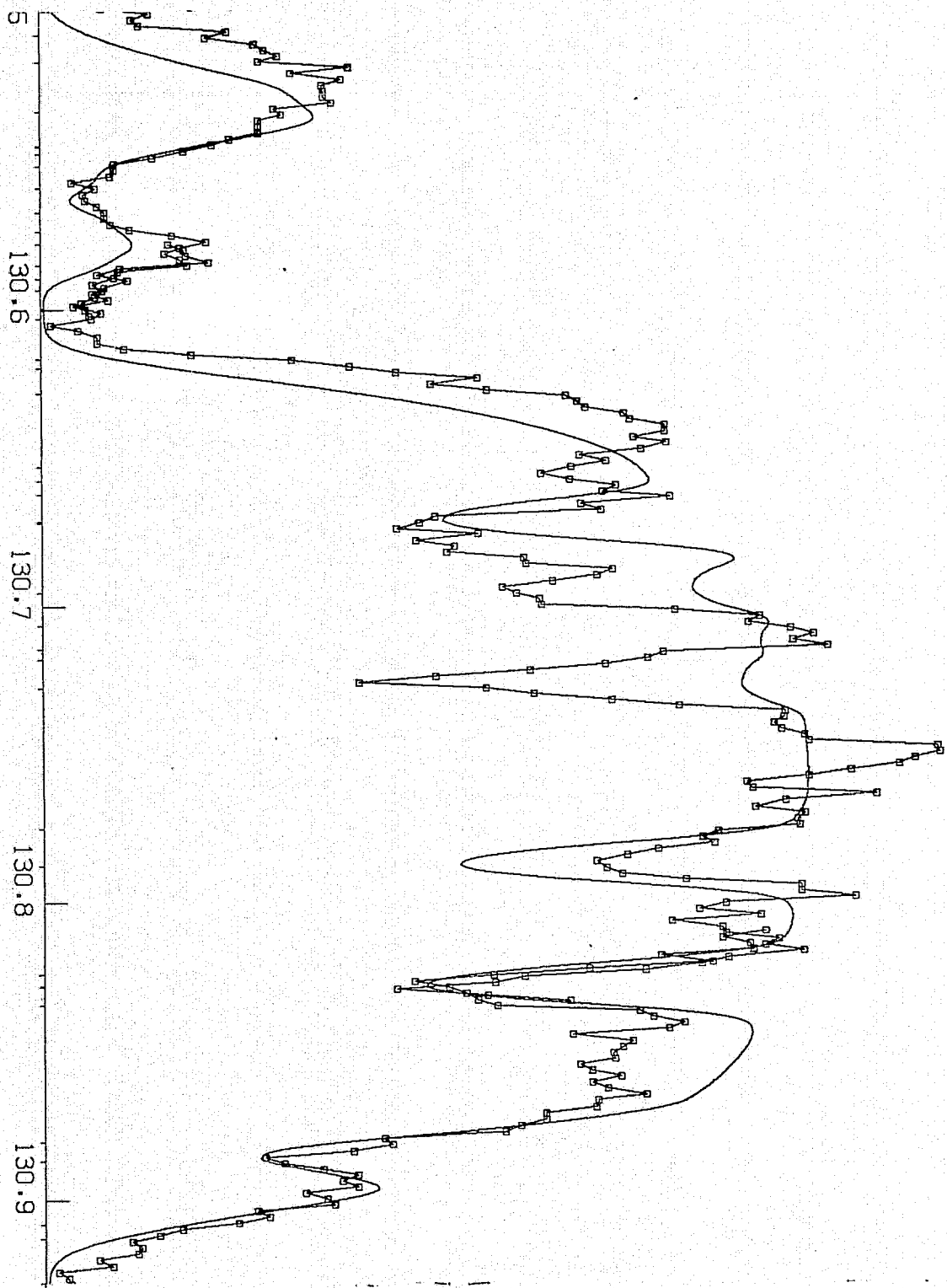
71	23.02	11966	944	52	24.02	17395	976
265	28.01	24788	662	220	28.01	53601	721
				253	23.02	11591	877
567	27.01	3350	222	543	28.01	53037	822
				788	7.01	15316	324
				614	7.01	15316	800
35	7.01	15316	487	21	26.02	93388	980
				268	26.02	70728	984
366	26.01	2430	981				
				866	14.01	76665	455
				55	25.01	29889	347
151	26.01	2430	965	150	14.02	52853	76
562	25.01	29919	966				
595	14.01	76665	613				
				778	25.01	29889	980
859	15.01	0	1	852	26.02	49576	395
				866	26.01	23796	876
75	26.02	89697	932	102	25.01	29951	727
118	26.02	93512	851				
168	6.00	0	0				
248	28.01	29070	920	263	23.02	11769	990
353	16.00	396	0				
				464	28.01	55018	978
603	28.01	54262	954				
643	24.02	20851	988				
792	26.01	15844	9	823	24.02	17272	989
877	16.00	396	0	869	26.02	92523	922
80	28.01	52738	847				
123	16.00	396	0				
172	28.01	52738	925	172	28.01	23108	954
237	28.01	55018	981	261	28.01	53601	868
281	28.01	55018	981				

Figure 8 (Continued)



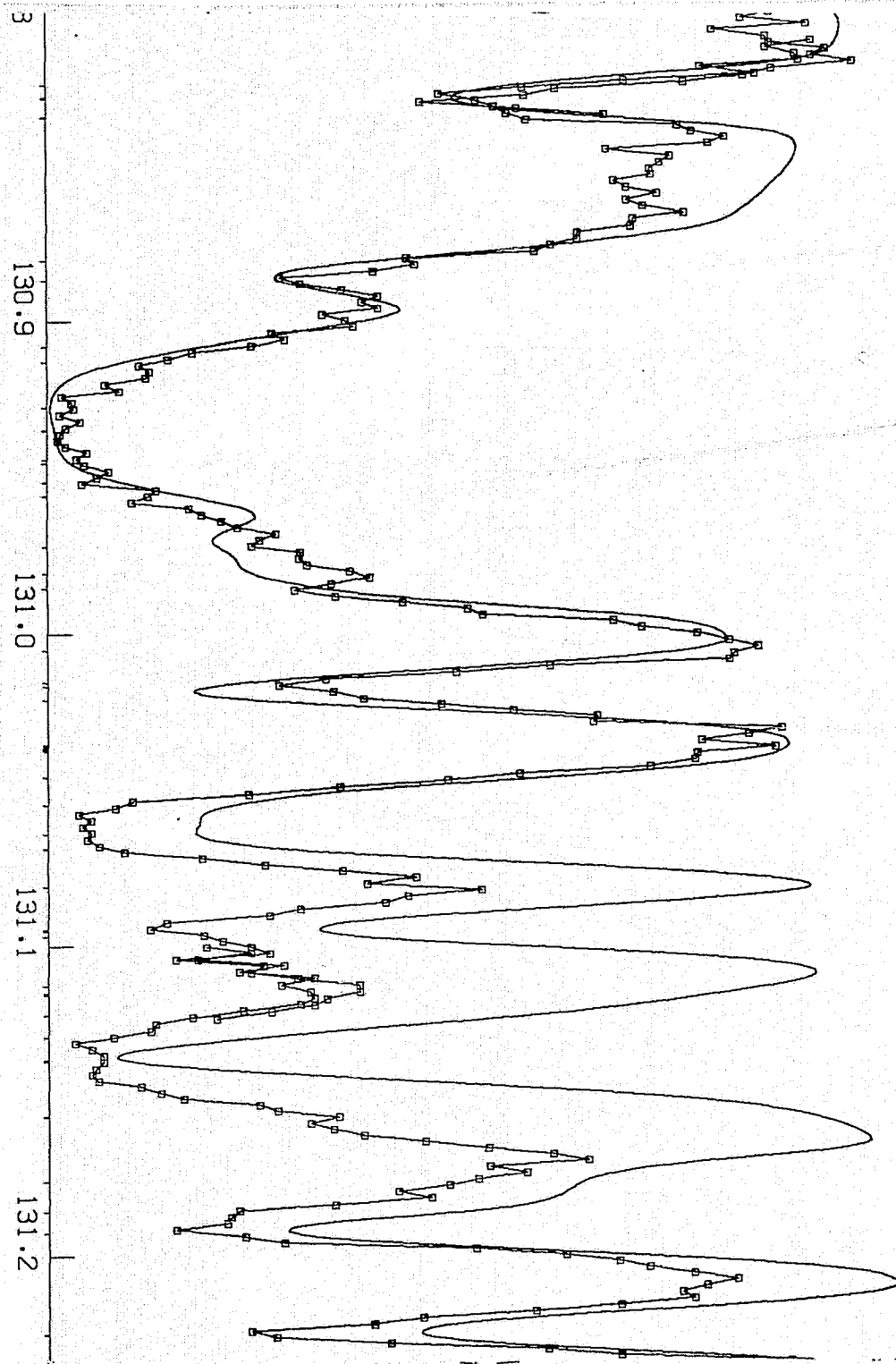
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118	26.02	93512	951				
168	8.00	0	0				
248	28.01	29070	920	263	23.02	11769	990
353	16.00	396	0				
				464	28.01	55018	978
603	28.01	54262	954				
643	24.02	20851	988				
792	26.01	15844	9	823	24.02	17272	989
877	16.00	396	0	869	26.02	92523	922
80	28.01	52738	847				
123	16.00	396	0				
172	28.01	52738	925	172	28.01	23108	954
237	28.01	55018	981	261	28.01	53601	869
285	28.01	57080	989				
320	14.02	53115	71	378	26.02	90483	985
448	16.00	0	0				
				575	26.02	70694	918
914	28.02	61339	982				
366	14.01	0	0				
471	15.00	0	654	475	15.01	164	1
595	28.01	55018	910				
640	20.01	13650	1	657	28.01	32499	986
659	15.01	164	1	677	28.02	62606	901
				857	8.00	158	0
79	24.02	20994	859				
				170	28.01	55018	682
				340	28.02	53703	590
455	28.01	53634	971	453	28.01	55018	985
480	15.01	164	1	457	26.02	90483	982
520	28.01			520	28.01	29070	989
591	14.01	55325	3				
674	20.01	13710	1	674	20.01	13710	15
				739	25.01	14593	988
				781	26.01	15844	3
				853	26.02	90423	949
				897	16.00	573	0
				937	23.02	28746	752
				28	8.00	226	0
165	25.01	29919	550				
195	23.02	11769	922				
280	28.01	54262	967				

Figure 8 (Continued)



79	24.02	20994	859			
				170	28.01	55018 682
				340	28.02	53703 590
455	28.01	53634	971	453	28.01	55018 986
480	15.01	164	1	457	26.02	90483 982
				520	28.01	29070 989
591	14.01	55325	3			
674	20.01	13710	1	674	20.01	13710 15
				739	25.01	14593 988
				781	26.01	15844 3
				853	26.02	90423 948
				897	16.00	573 0
				937	23.02	26746 752
				28	8.00	226 0
165	25.01	29919	550			
195	23.02	11769	922			
280	28.01	54262	967			
529	28.01	54262	982			
				577	23.02	26746 976
				621	28.01	52738 900
710	25.01	29951	725	714	12.01	35669 21
952	27.01	4028	391			
				63	24.02	20851 974
				145	28.01	54262 811
				180	28.01	53634 988
277	28.01	54262	614			
				748	26.02	70694 956
875	12.01	35669	13			
239	26.02	89783	988			
279	12.01	35760	279	281	12.01	35760 12
				342	26.02	70728 946
801	26.01	2837	57			
				855	28.01	0 0
79	28.01	57420	985			
126	28.01	53601	989			
273	14.01	287	0			

Figure 8 (Continued)



239 26.02 89783 988
279 12.01 35760 279 281 12.01 35760 12
342 26.02 70726 946

801 26.01 2837 57 865 28.01 0 0

79 28.01 57420 985
126 28.01 53601 989

273 14.01 287 0
350 24.02 25725 445
443 12.01 35760 8 453 14.01 55309 4
516 24.02 20994 961
558 23.02 11966 974

724 14.01 55325 20
809 26.02 82382 941 857 15.01 469 1

51 28.01 55417 989
155 6.00 10192 5 166 26.01 16369 884
212 16.00 396 0

357 28.01 57420 989 374 6.00 10192 970
361 28.01 57420 987 370 26.02 89907 927
370 26.02 89907 982 457 28.01 51557 763
541 7.00 28639 1

637 6.00 10192 41
685 15.01 469 0
804 23.02 11591 979

950 7.00 28839 2 944 7.00 28838 1
966 26.02 89907 958

126 27.01 4028 824 149 24.02 20851 979
153 28.01 55417 954 219 26.01 1872 152

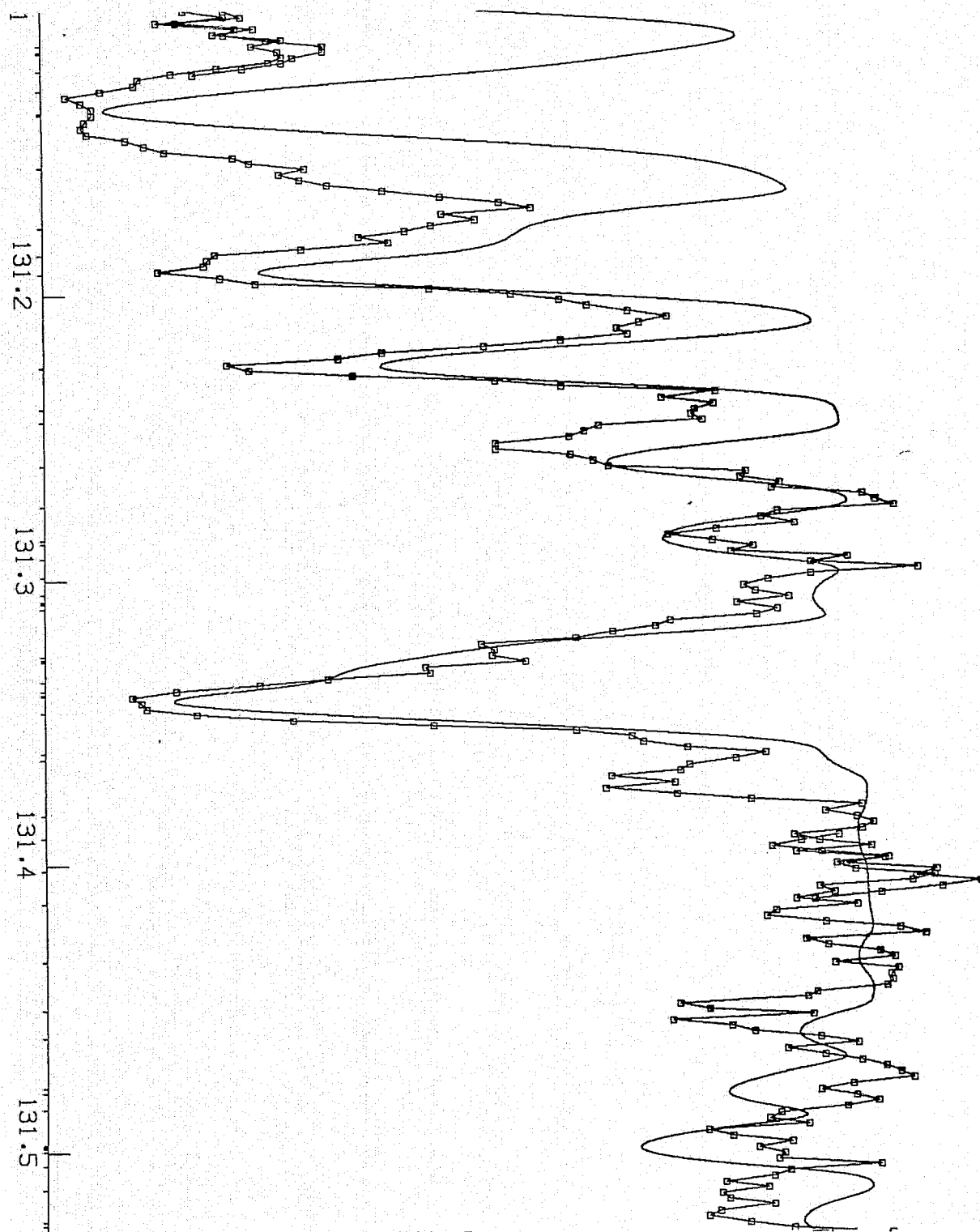
288 26.01 2430 88
363 6.00 10192 0 369 26.02 92523 963

548 24.02 20851 987 546 26.02 62606 985

758 26.01 16369 4 856 27.01 4560 571
924 6.00 10192 1

247 6.00 10192 2

Figure 8 (Continued)



126 27.01	4028 824	149 24.02	20851 979
153 28.01	55417 954	219 26.01	1872 152
288 26.01	2430 88		
363 6.00	10192 0	369 26.02	92523 963
548 24.02	20851 997	546 28.02	62606 985
758 26.01	16369 4		
924 6.00	10192 1	856 27.01	4550 571
247 6.00	10192 2		
392 6.00	10192 870		
440 28.01	54557 980		
591 14.02	62884 323		
		734 23.01	208 981
865 7.00	28839 844	855 6.00	10192 194
921 26.02	70725 973		
46 26.02	63466 908	986 26.02	70728 978
71 7.00	28838 912	78 7.00	28839 912
96 26.02	89783 965		
277 7.00	28838 912	267 16.00	573 1
354 23.02	12187 513	283 7.00	26839 912
398 26.02	63486 979	387 6.00	10192 3
		403 28.01	53365 890
		464 6.00	10192 2
607 26.01	3117 699	629 6.00	10192 970
		823 23.01	106 971
		903 28.01	53365 926
		17 24.02	20894 965
		131 26.02	49576 978
		332 26.02	63425 908
		504 26.02	90423 978
601 26.02	40999 610		
789 26.01	16369 379	771 28.01	53365 733
848 28.01	53365 711		
979 7.00	28839 912	974 7.00	28838 912
995 15.00	0 17	983 23.01	339 925
		45 26.02	63466 970
129 26.02	63425 972		
242 26.02	89907 997	242 26.02	89907 979
995 28.01	63425 997		

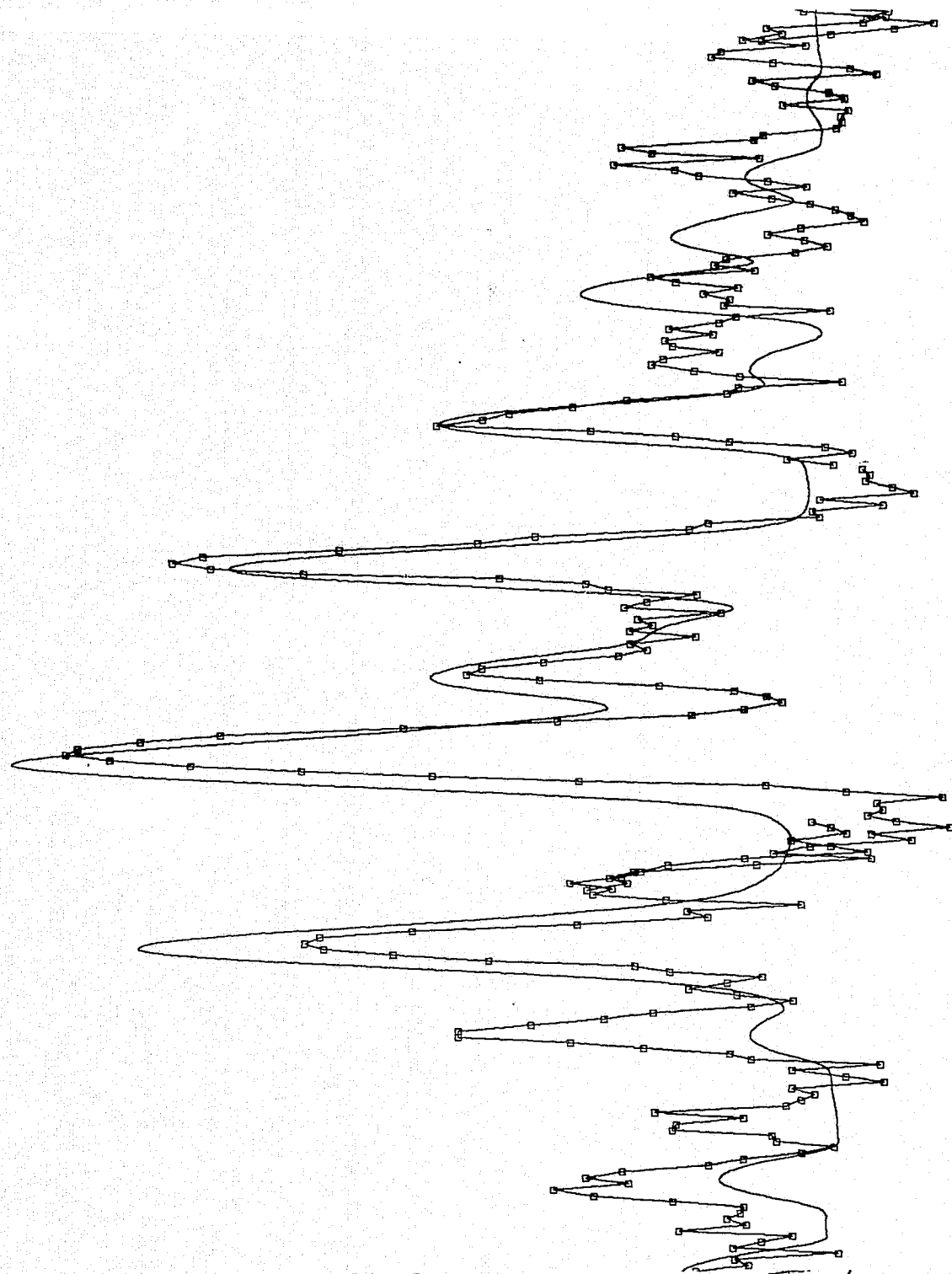
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131.5

131.6

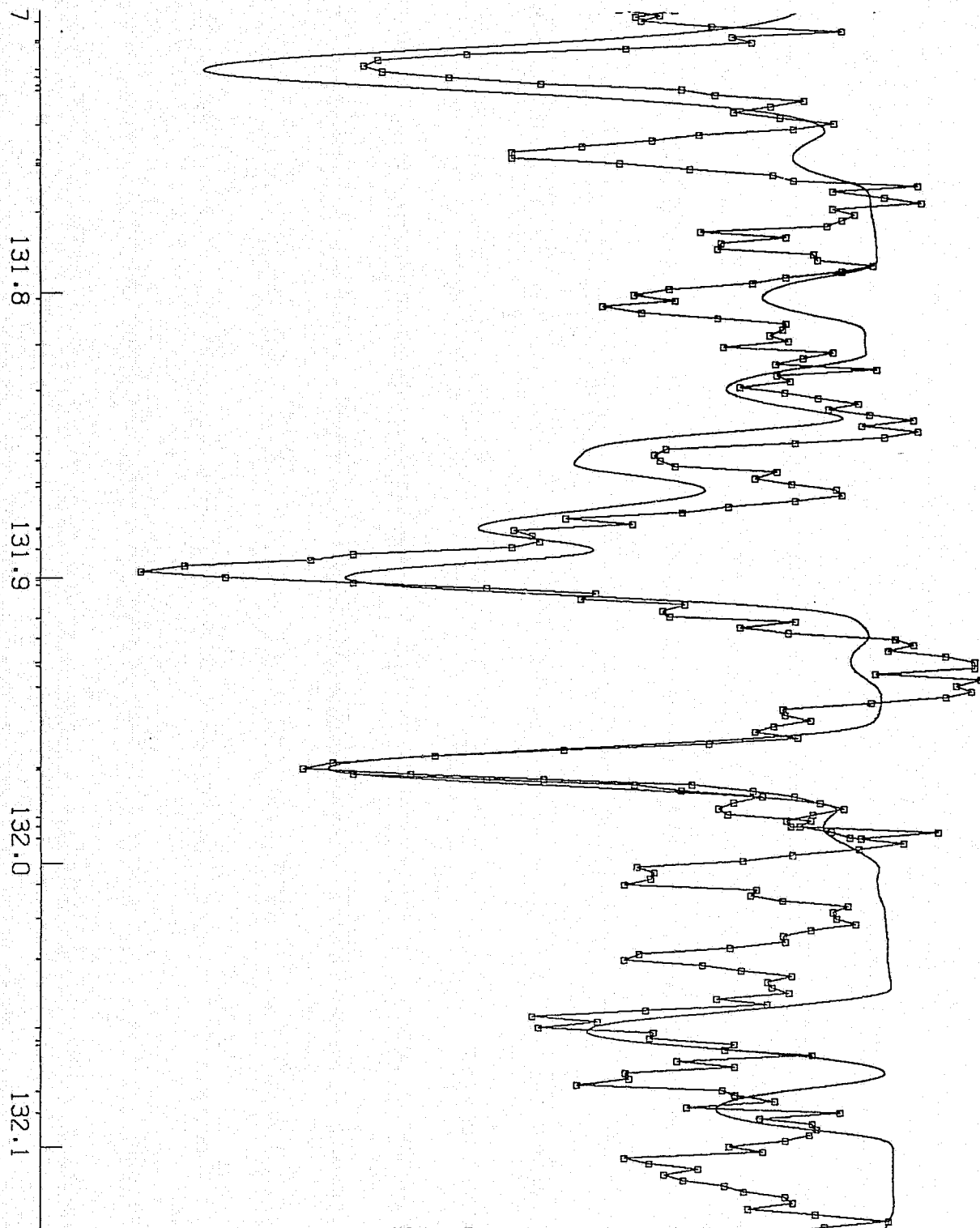
131.7

131.8



17	24.02	2055	363		
131	26.02	49576	978		
332	26.02	63425	908		
504	26.02	90423	879		
601	26.02	40999	610		
789	26.01	15369	379	771	28.01
848	28.01	53365	711	53365	733
979	7.00	28839	912	974	7.00
995	15.00	0	17	983	23.01
129	26.02	63425	972	45	26.02
242	26.02	89907	987	242	26.02
255	28.01	53365	556	89907	979
419	27.01	4950	734	414	26.02
436	7.00	28839	12	430	7.00
559	28.01	55018	945	452	24.02
590	23.01	208	954	540	26.02
679	26.02	62410	957	89597	987
842	26.02	63466	986	430	7.00
918	6.00	10192	1	28839	10
36	7.00	28839	912	452	24.02
120	25.02	68899	988	540	26.02
157	25.01	38366	890	50483	951
291	7.00	28839	6		
406	24.02	25781	515		
557	16.00	0	0	501	28.01
637	16.00	0	2	54176	951
869	26.02	40999	989	628	16.00
905	26.02	89783	988	0	0
955	28.01	53365	921		
45	28.01	53496	915		
114	28.01	55018	976	122	28.01
244	26.01	7955	986	53496	901
271	23.02	11966	578	217	28.01
409	28.01	53365	982	0	0
545	26.01	20340	988	290	26.01
552	26.02	40999	668	7955	783
717	26.02	93388	989		
19	28.01	53496	352		
180	27.01	5204	851		

Figure 8 (Continued)



45	28.01	53495	915		
114	28.01	55018	976	122	28.01 53496 901
244	26.01	7855	986	217	28.01 0 0
271	23.02	11966	578	290	26.01 7955 783
409	28.01	53365	982		
545	26.01	20340	988	531	28.01 53496 680
				552	26.02 40959 868
717	26.02	93388	989		
				19	28.01 53496 352
				180	27.01 5204 861
				339	26.01 2837 86
				501	7.00 28839 830
564	26.01	20516	7	588	27.01 4950 801
680	15.00	0	98	665	25.01 38542 983
823	7.00	28838	5	830	7.00 28839 912
				899	28.01 24788 910
999	7.00	28838	1	6	7.00 28839 2
25	15.00	0	112		
				141	26.02 49148 894
				211	25.01 38542 987
310	28.01	55018	911	296	26.02 73727 881
				381	24.02 18581 990
677	7.00	28839	1	570	7.00 28838 2
838	27.01	5204	861		
871	26.02	93512	951		
911	26.01	20516	720	914	26.02 82494 971
71	24.02	43285	525		
192	28.01	55018	963		
334	27.01	4560	988	331	26.02 90483 985
638	28.01	56075	987	577	26.01 3117 49
				623	26.01 20340 134
798	28.01	55018	958		
874	26.01	2430	52		

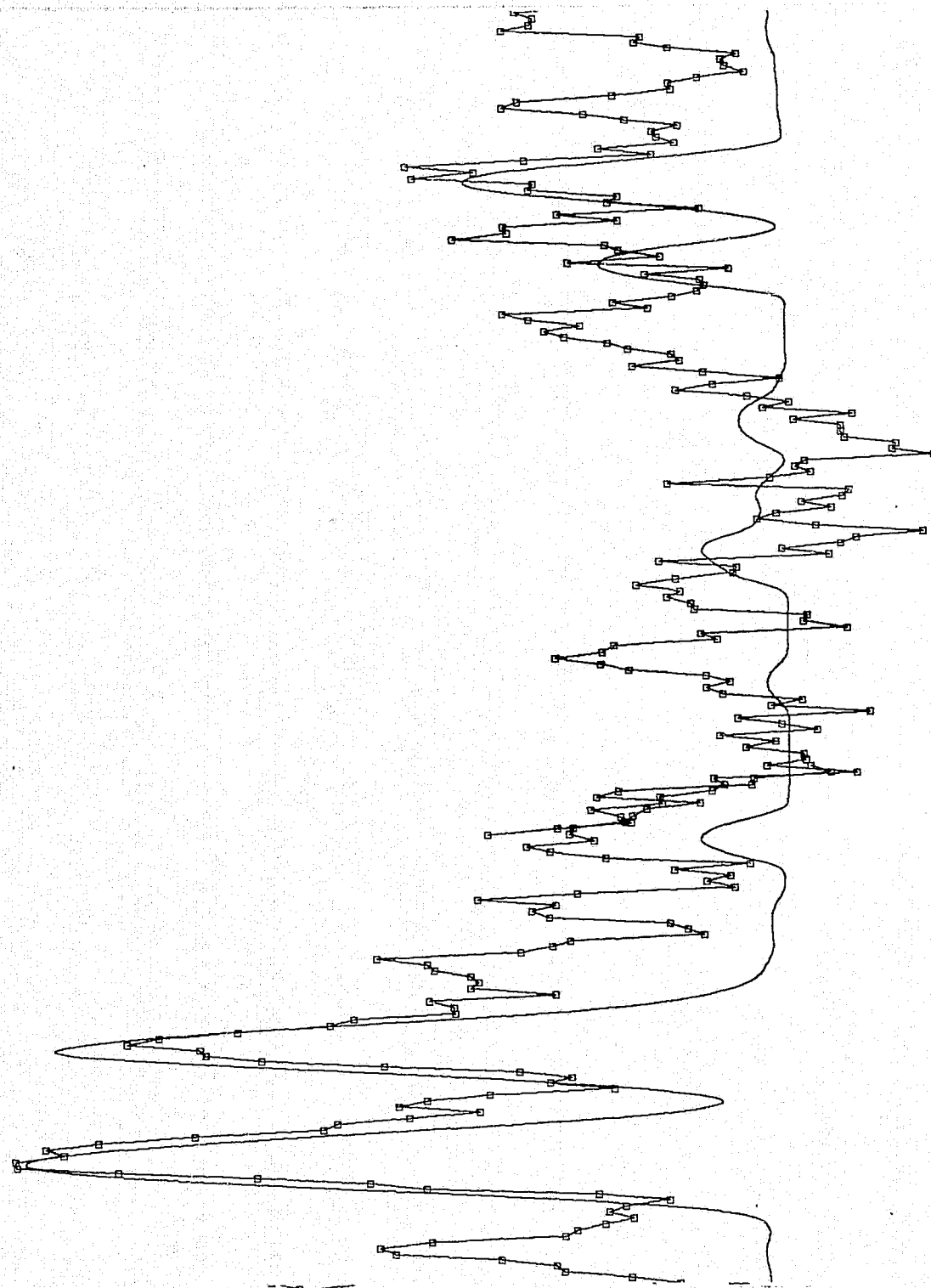
Figure 8 (Continued)

132.1

132.2

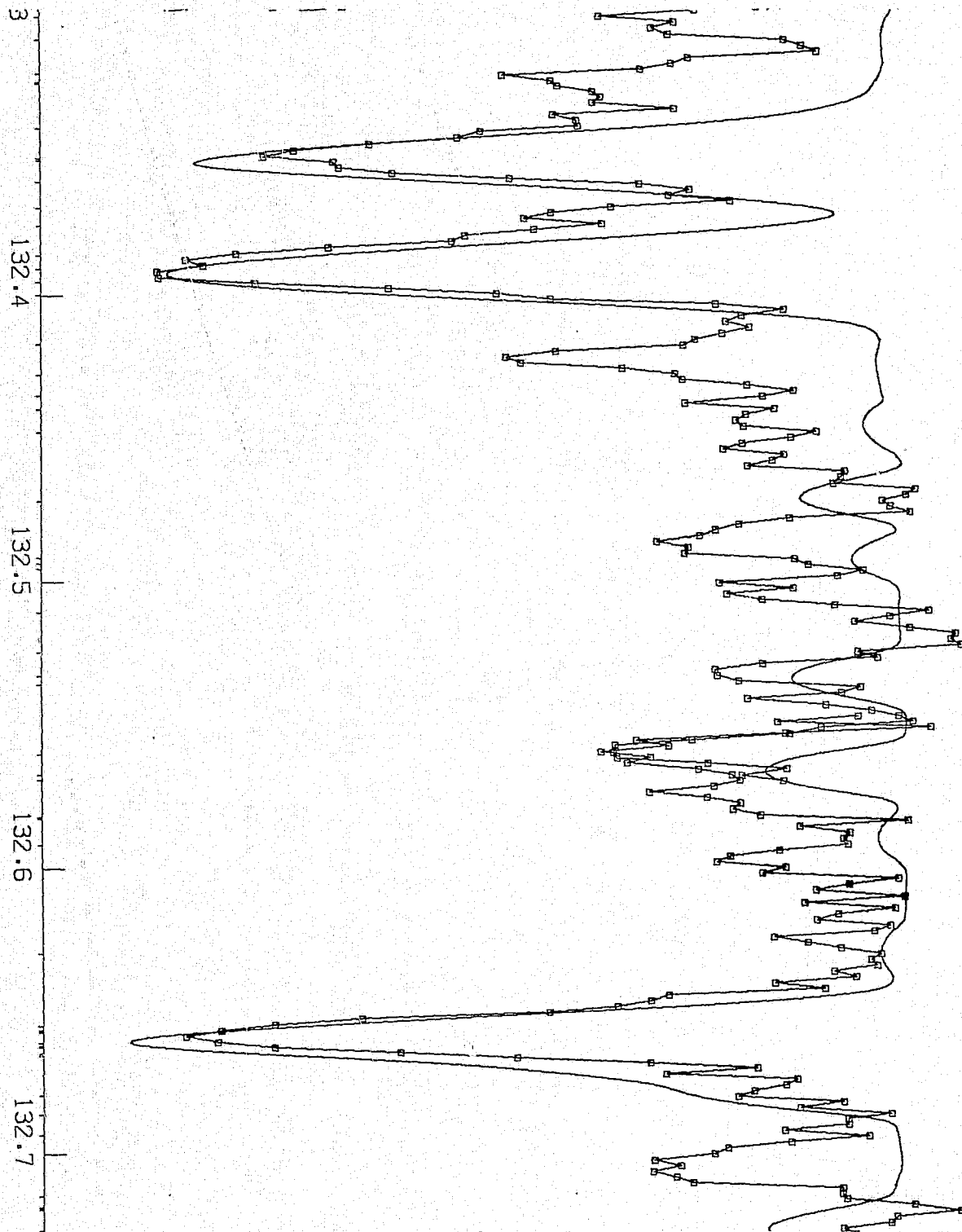
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132.4



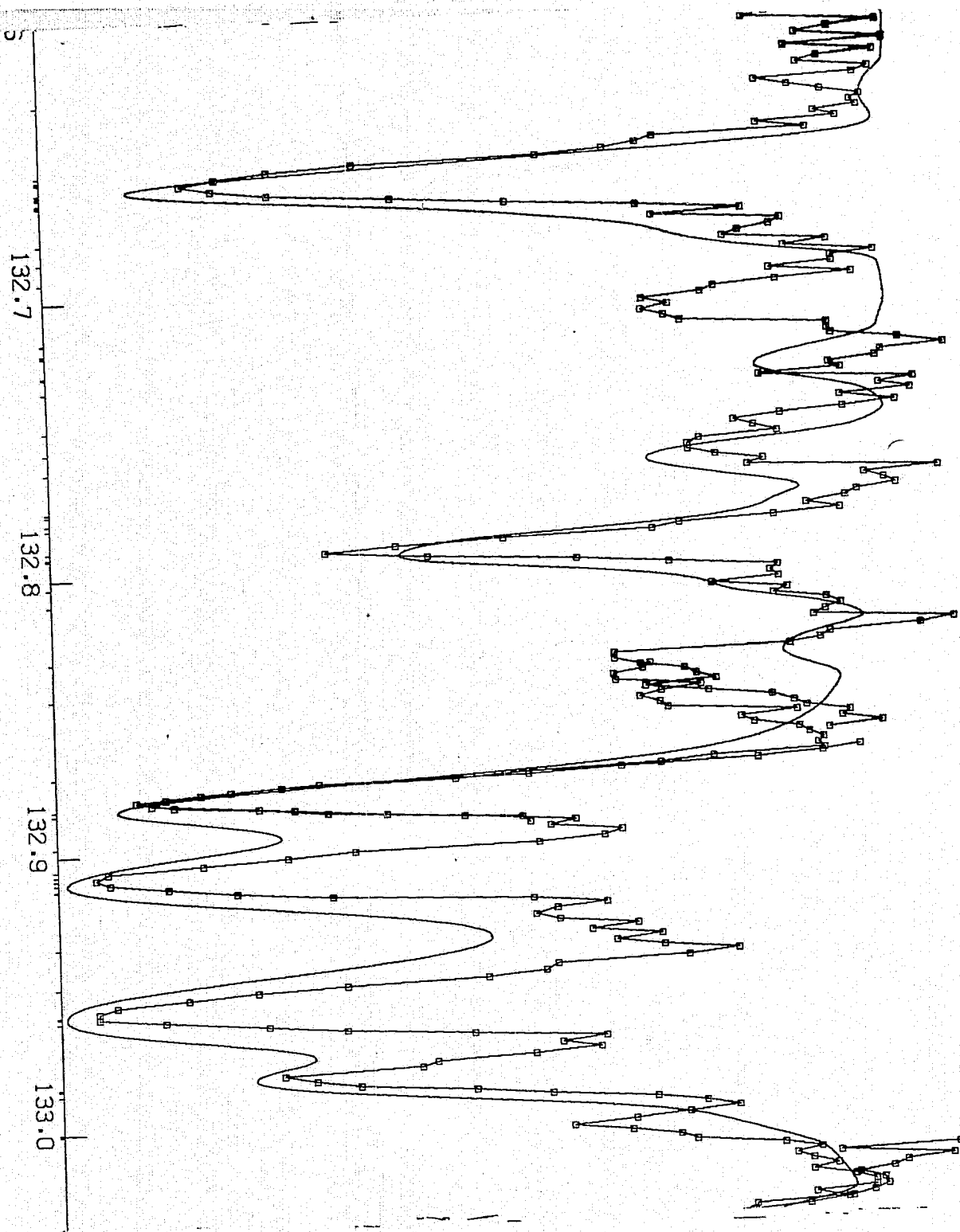
71	24.02	43285	925		
192	28.01	55018	963		
334	27.01	4560	988	331	26.02 90483 986
638	28.01	55075	987	577	26.01 3117 49
				623	26.01 20340 134
798	28.01	55018	958		
874	26.01	2430	52		
				332	28.02 61339 933
425	15.00	0	805	414	26.02 73849 941
482	28.01	55018	988	432	28.01 56075 945
				655	24.02 25781 868
				704	28.01 53634 935
804	28.02	54657	825		
889	26.01	2837	493		
				304	28.02 61339 888
767	26.02	82382	988		
830	24.02	25848	595	828	28.01 56075 952
877	27.01	4950	978		
				28	27.01 5204 979
				107	28.01 54262 929
230	28.01	25036	987		
264	25.01	38806	990	258	26.02 82410 989
				419	28.01 56075 813
521	16.00	395	0	530	16.00 395 0
605	26.01	20805	20		
				696	26.02 42896 988
758	25.01	38806	958		
				862	6.01 74932 197
				906	6.01 74932 35
951	6.01	74930	23		
956	6.01	74930	197		
167	24.02	18510	988		
273	26.01	8846	874		

Figure 8 (Continued)



			28 27.01	5204 919
			107 28.01	54262 929
230 28.01	25036 987	258 26.02	82410 989	
264 25.01	38806 990			
		419 28.01	56075 813	
521 16.00	395 0	530 16.00	395 0	
605 26.01	20805 20			
		696 26.02	42896 988	
758 25.01	38806 990			
		862 6.01	74932 197	
951 6.01	74930 23	906 6.01	74932 35	
956 6.01	74930 197			
167 24.02	18510 988			
273 26.01	8846 874			
395 28.02	63472 941	347 23.01	339 986	
474 28.01	55299 783			
		715 26.02	50184 537	
		912 26.01	8391 893	
951 25.01	14325 954	932 26.02	40999 799	
		107 28.01	55299 953	
243 28.01	55299 965			
327 26.02	50184 839			
357 28.01	55299 488			
601 26.02	57221 978			
675 26.01	20805 174	692 28.01	29070 981	
823 28.01	55371 990	819 28.02	62806 956	
917 26.02	40999 844			
		294 28.01	55417 963	
565 7.00	28838 3	550 28.01	55417 828	
608 26.02	40999 947	571 7.00	28838 1	
624 28.01	56371 888	619 28.02	63472 970	
649 16.00	573 0	647 26.02	49576 968	
		654 26.02	57295 961	
792 26.01	3117 26			
		858 26.02	84671 982	
		931 26.02	50276 990	
		147 26.02	42896 958	
191 28.01	58705 987	165 28.01	55417 990	
263 26.02	57221 828			

Figure 8 (Continued)



294 28.01 55417 883

565	7.00	28838	3	550	28.01	55417	828
606	26.02	40999	947	571	7.00	28839	1
624	28.01	56371	888	619	26.02	63472	970
649	16.00	573	0	647	26.02	48578	958
				654	26.02	50295	961

792 25.01 3117 26

858 26.02 84671 982

931 28.02 50278 990

191 28.01 58705 987

147 26.02 42896 958

185 28.01 55417 990

267 26.02 50295 520

263 26.02 57221 828

322 28.01 55417 804

465 25.01 38366 985

545 26.02 49576 779

614 22.02 8472 93

754 28.01 56371 689

764 24.02 18451 989

797 28.01 55417 970

797 26.01 2430 664

813 24.02 43286 836

918 7.00 28838 2

900 23.02 27727 876

924 7.00 28839 2

28 26.01 2837 262

92 28.02 54657 660

302 14.01 76665 821

436 24.02 43321 979

718 26.02 50412 988

834 6.00 0 0

849 28.01 52738 937

868 28.01 56424 786

84 6.00 16 0

51 23.02 16810 954

123 6.00 16 0

100 6.00 16 0

121 26.02 88847 945

70 28.01 54262 879

333 26.02 50412 936

477 28.01 55018 992

600 6.00 43 0

577 6.00 43 0

581 28.01 54262 891

833 22.02 0 420

838 20.01 13650 1

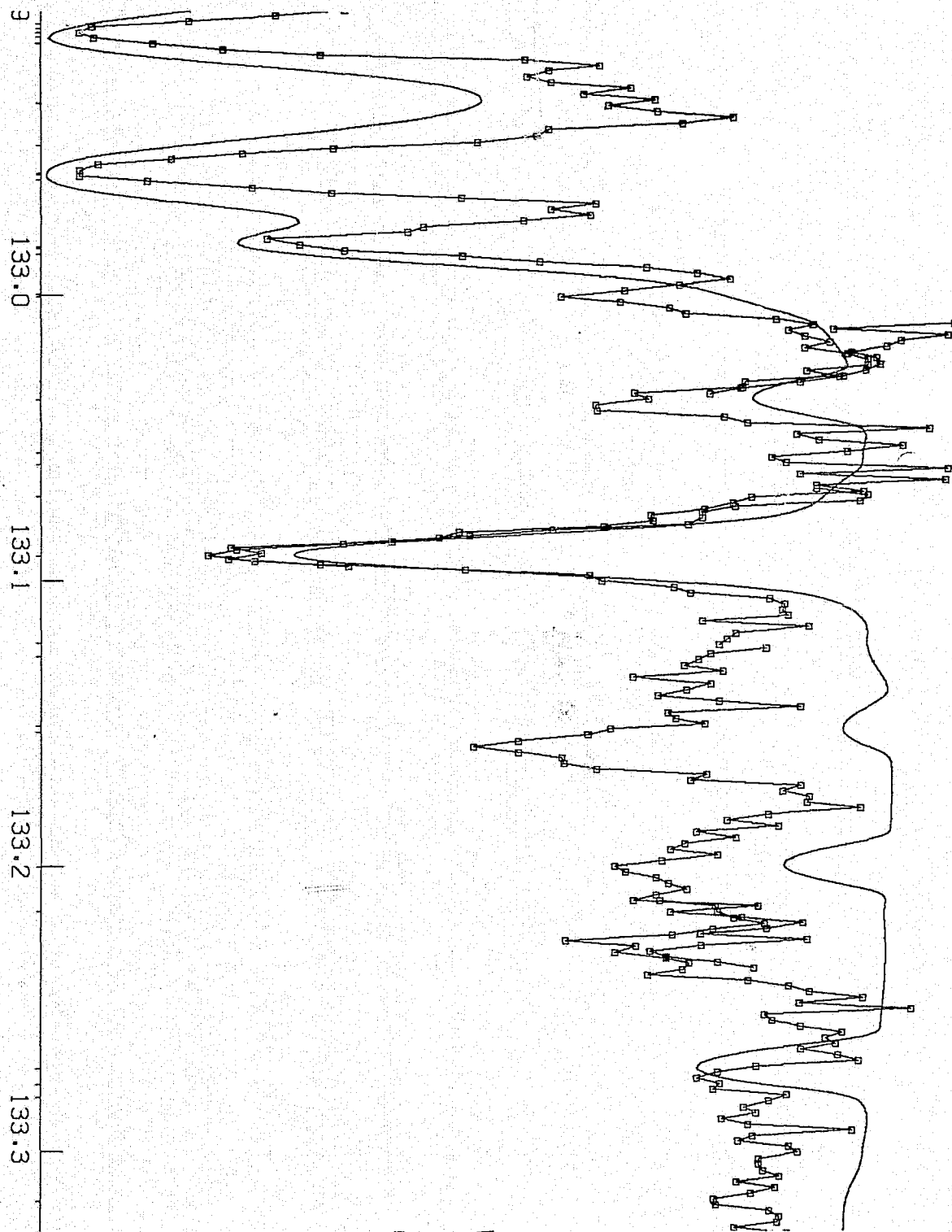
839 28.01 58705 989

859 28.01 56424 878

996 26.01 8680 803

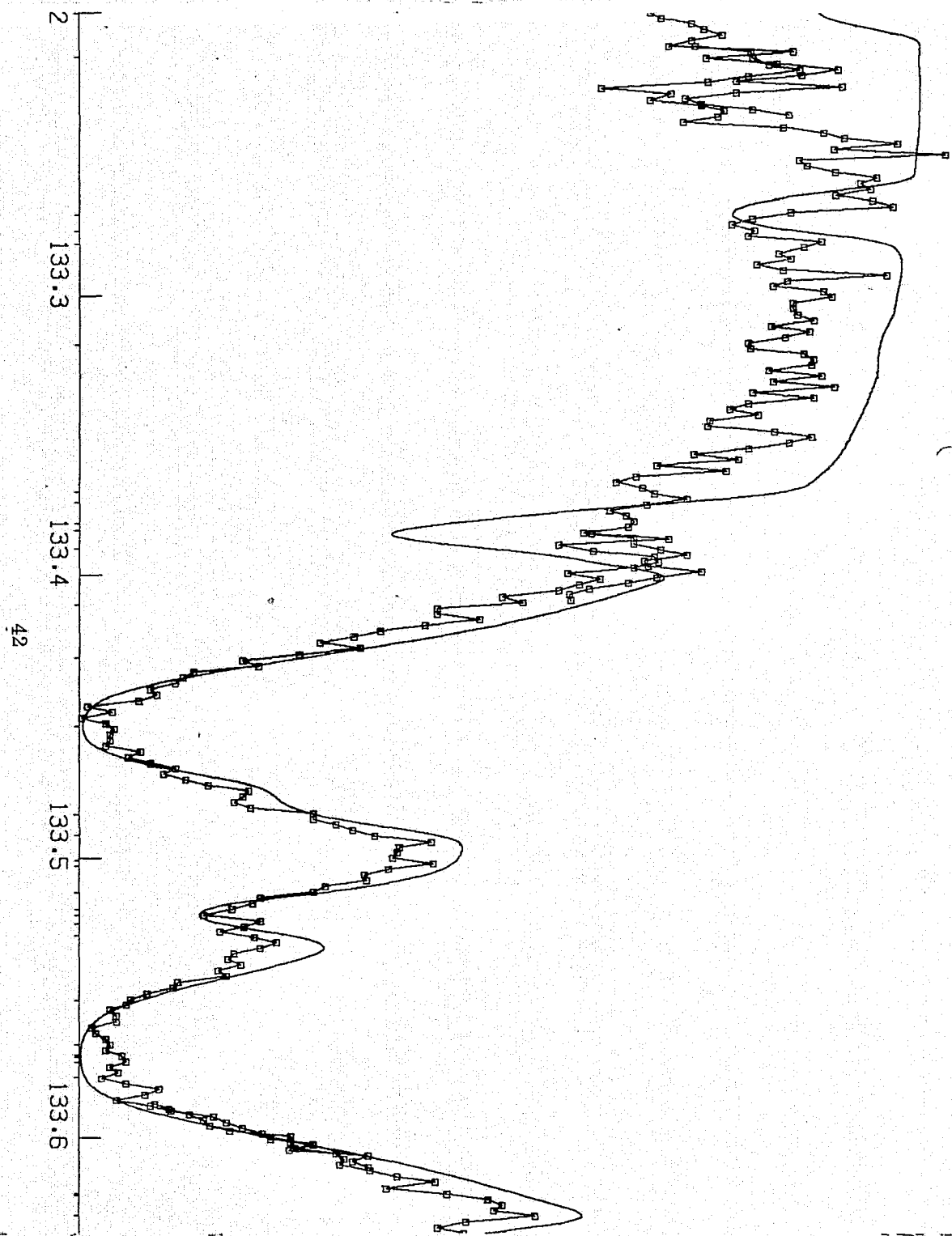
5 26.02 73727 901

Figure 8 (Continued)



84	6.00	16	0	0	51	23.02	16810	954
123	6.00	16	0	0	100	6.00	16	0
121	26.02	86847	845		70	28.01	54262	879
					333	26.02	50412	936
477	28.01	55018	982					
500	6.00	43	0	577	6.00	43	0	
				581	28.01	54262	891	
833	22.02	0	420	838	20.01	13650	1	
839	28.01	58705	983	859	28.01	55424	878	
996	26.01	8680	803	5	26.02	73727	901	
363	26.02	50276	505					
				549	28.01	54262	977	
590	25.01	38542	980					
				701	26.02	50295	849	
912	20.01	13710	1	912	20.01	13710	7	
				218	24.02	43304	978	
				266	28.01	55018	926	
				506	25.01	14325	793	
				530	24.02	43321	661	
2	23.02	16977	452					
157	26.02	73849	975					
712	26.01	18360	68					
767	28.01	54262	912					
				812	28.01	58705	972	
				172	28.01	54262	952	

Figure 8 (Continued)



157 26.02 73849 975

712 26.01 18360 68
767 28.01 54262 912

812 28.01 58705 972

172 28.01 54262 952

701 26.02 73935 949
739 25.01 14593 989
839 26.01 21308 150
814 16.00 0 4
903 26.01 18360 15

103 28.01 56075 929

281 28.01 54557 789

532 6.01 0 0

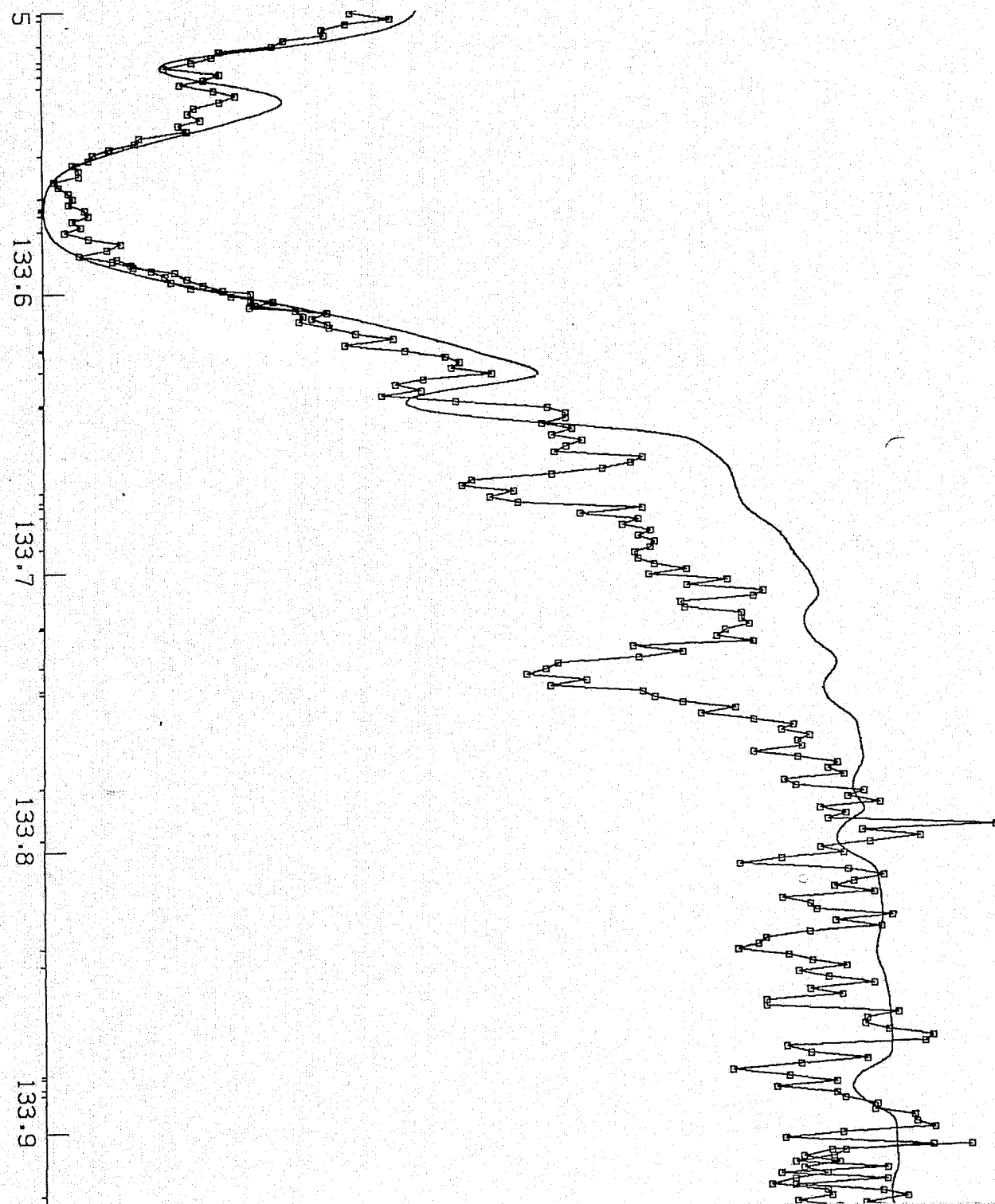
844 15.02 0 179
917 28.02 55952 970
7 28.02 55406 980
122 23.02 16810 495
201 28.01 1506 0
231 26.02 70725 914
273 25.01 38806 975
182 7.00 28839 615

508 28.02 82277 988

701 28.01 56075 967
726 17.00 0 0
663 6.01 63 0
708 6.01 63 0
702 28.01 54557 570
782 28.01 54557 795

196 26.02 63425 937
273 25.01 14593 941
202 28.01 54557 899

Figure 8 (Continued)



1	20.02	33400	300	27	26.01	2837	346
122	23.02	16810	495				
201	28.01	1506	0	182	7.00	28839	615
231	26.02	70725	914				
273	25.01	38806	975				

508 28.02 82277 988

701	28.01	55075	967	653	8.01	63	0
726	17.00	0	0	708	6.01	63	0
				702	28.01	54557	570
				782	28.01	54557	795

196 26.02 63425 937 202 28.01 54557 899
273 25.01 14593 941

394 7.00 28838 371 401 7.00 28839 14

760	28.01	25036	985	708	26.01	21251	939
793	26.02	73849	931	743	26.01	21430	899

911 28.02 82172 960

191	7.00	28838	912	199	7.00	28839	912
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338 26.01 21581 957

435 26.02 50184 848 422 25.01 14325 987

773 24.02 43304 900

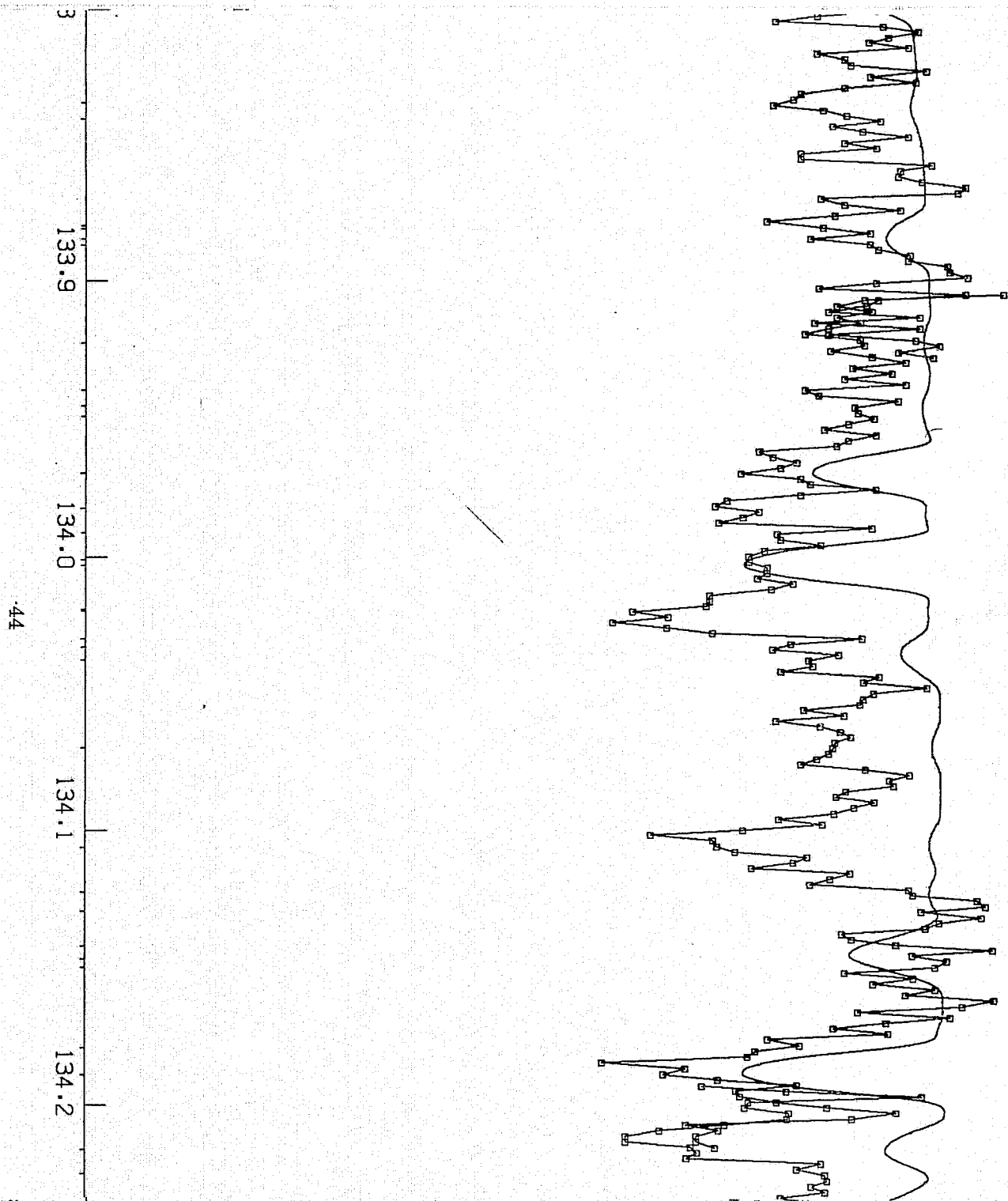
956 28.01 54557 827 960 28.01 56075 895

407 28.01 57080 977 347 26.02 50184 959

797	26.02	63494	976	807	26.02	63494	988
843	28.01	23108	763	867	28.01	56075	947

223 28.01 57080 952

Figure 8 (Continued)



407 28.01 57080 977 347 26.02 50184 959

797 26.02 63494 976 807 26.02 63494 986
843 28.01 23108 763 867 28.01 56075 947

223 28.01 57080 952

395 28.01 56371 973 451 26.01 21581 989
490 28.01 56075 938

693 22.02 8472 360

823 26.02 63466 950

912 26.01 21430 956 28 26.01 3117 43
9 28.01 53365 849

194 28.01 56075 973 189 26.02 63486 958
326 26.02 50295 924 296 26.02 83645 987
375 28.01 57080 829

695 26.02 63466 948

62 26.01 21711 918 61 26.02 63486 986

223 26.02 50295 932

295 28.02 56308 986

421 28.02 55408 810
470 14.02 142944 777 500 14.02 142948 920

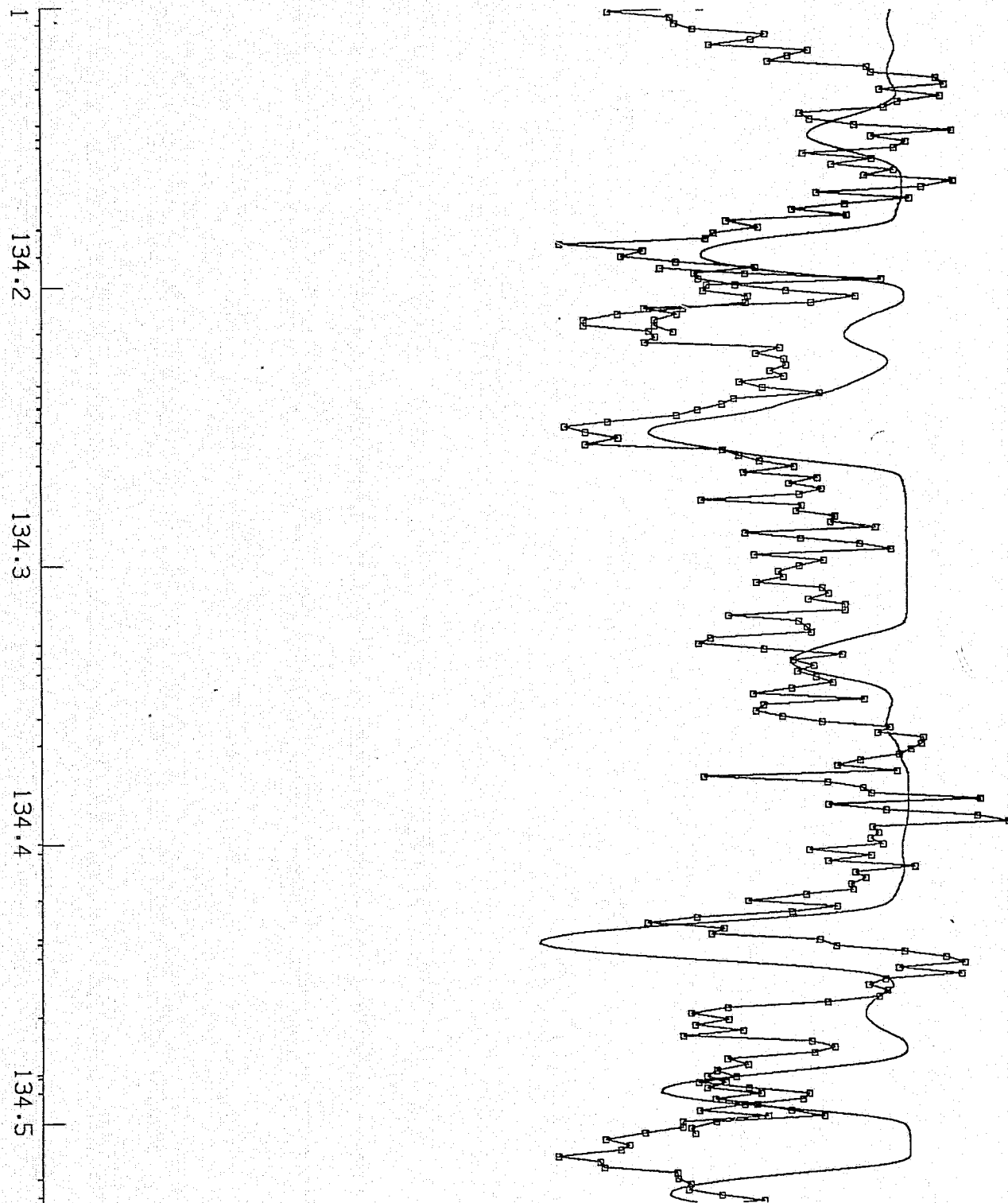
792 26.01 21711 928

890 20.01 0 27

161 28.02 55408 723
247 28.01 53365 910

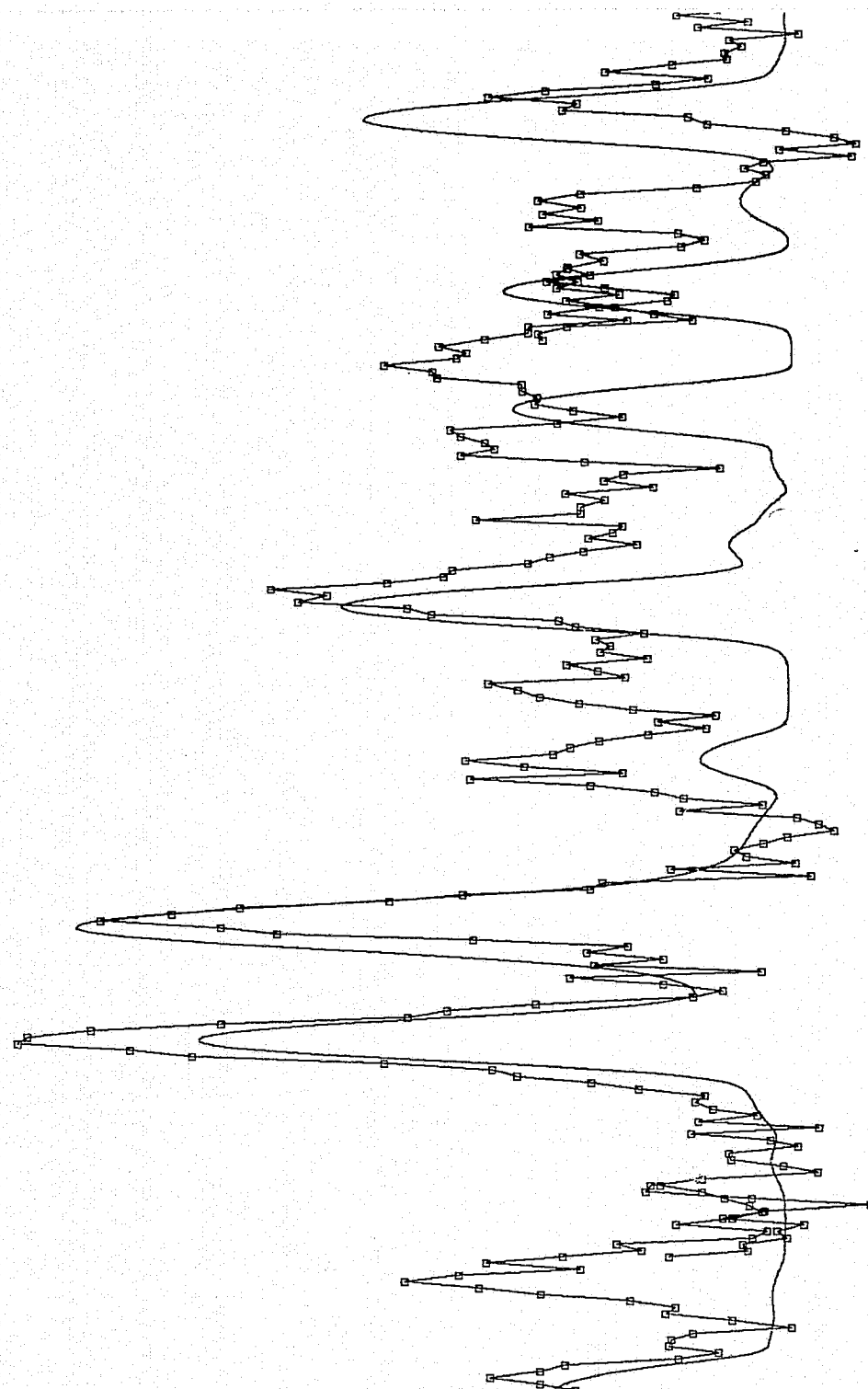
349 14.02 142944 972

Figure 8 (Continued)



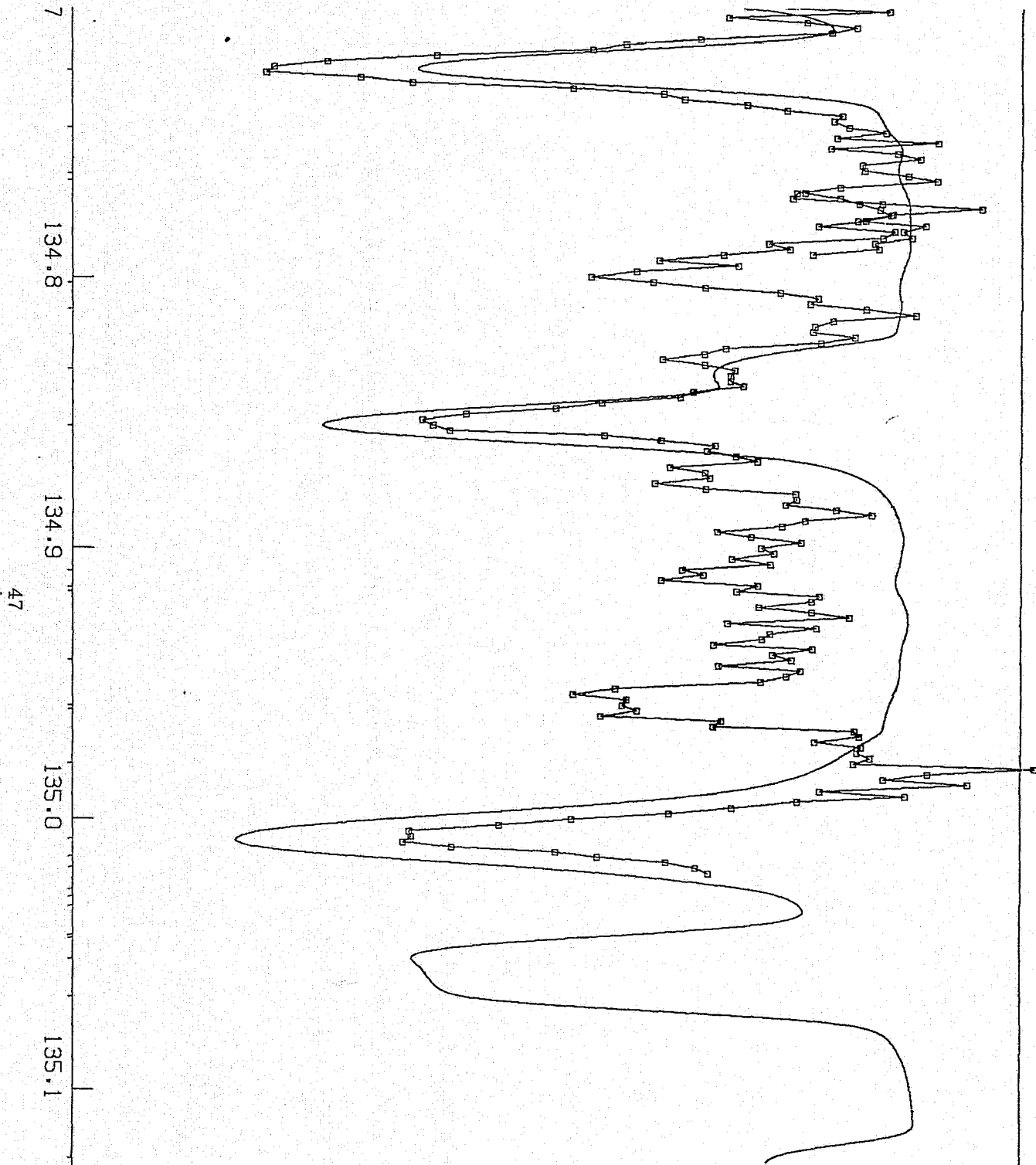
62 26.01	21711 918	61 26.02	63486 986
		223 26.02	50295 932
		295 28.02	56308 988
		421 28.02	55406 810
470 14.02	142944 777	500 14.02	142946 820
792 26.01	21711 928		
		890 20.01	0 27
161 28.02	55406 723		
247 28.01	53365 910		
		349 14.02	142944 922
		389 14.02	142946 825
430 14.02	142948 923	433 26.02	50412 958
478 26.02	57221 535		
551 25.01	14593 884	554 20.01	0 39
633 26.01	21581 962		
283 28.01	56371 953		
330 26.01	18886 691	332 26.02	50412 708
390 14.02	142948 860	390 14.02	142946 924
		546 28.01	56371 877
644 26.01	55417 936		
997 26.02	49148 983	29 26.02	84159 984
197 28.01	56371 968		
353 25.01	32787 517	337 28.01	56371 983
407 28.01	25036 984	357 15.02	559 156
		617 28.01	53495 737
836 28.02	52606 986	825 28.01	56371 982
890 15.02	559 310		
197 26.02	63425 983		
		262 26.01	10360 11

Figure 8 (Continued)



			29 26.02	84159 984
197 28.01	56371	968		
353 25.01	32787	517	337 28.01	56371 983
407 28.01	25036	984	357 15.02	559 156
			617 28.01	53496 737
836 28.02	62606	996	825 28.01	56371 982
890 15.02	559	310		
197 26.02	63425	983		
			262 26.01	18960 11
			341 28.01	57420 985
			416 28.01	23795 853
608 25.01	32856	834		
642 25.01	32858	972	649 26.02	70725 983
716 26.02	70728	793		
878 28.01	0	0		
944 25.02	63466	941	937 25.01	14781 925
358 26.02	70594	674	334 28.01	55018 985
			578 25.02	68899 940
884 14.01	42932	4		
			987 26.02	70728 957
240 17.00	0	0		
446 23.02	28746	913		
644 28.01	55299	986	618 25.02	68892 952
			19 26.02	87901 959
114 25.01	14901	980		
			335 28.01	82108 117

Figure 8 (Continued)

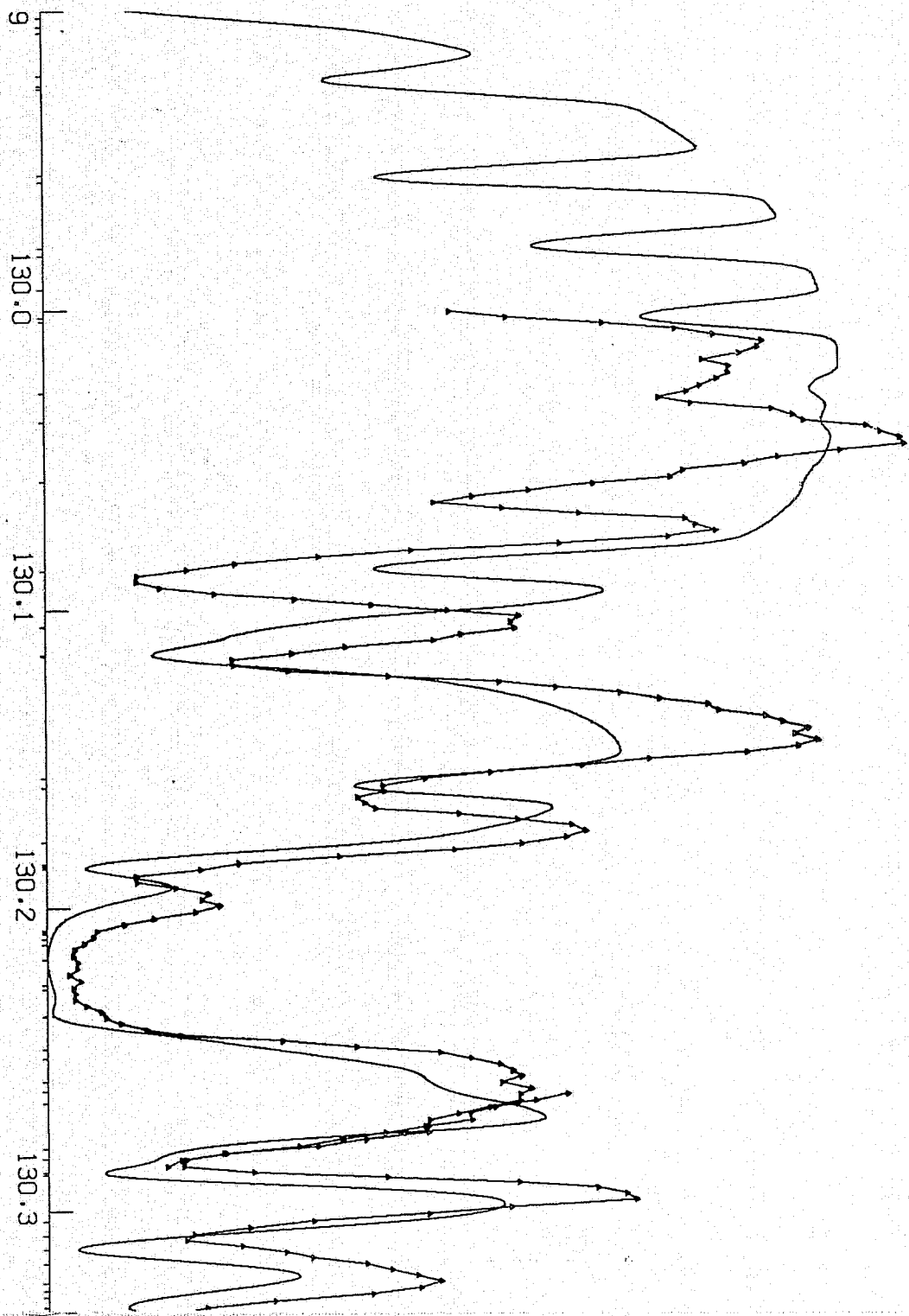


47

240	17.00	0	0
446	23.02	28746	913
644	28.01	55299	986
618	25.02	68892	952
19	26.02	87901	959
114	25.01	14901	980
335	28.01	23108	117
543	14.01	42824	4
84	28.01	55299	955
158	26.02	49576	970
143	28.02	83033	984
415	25.01	32787	959
593	28.01	55299	976
582	28.01	32523	972
793	28.01	55417	879
72	14.01	43107	3
137	26.02	63494	941
176	13.01	59849	299
286	25.01	14781	955
321	28.01	55417	876
438	26.02	63494	965
428	26.02	63494	866
516	14.01	42932	7
656	14.01	42824	10
249	28.02	55952	794
688	28.01	55706	973

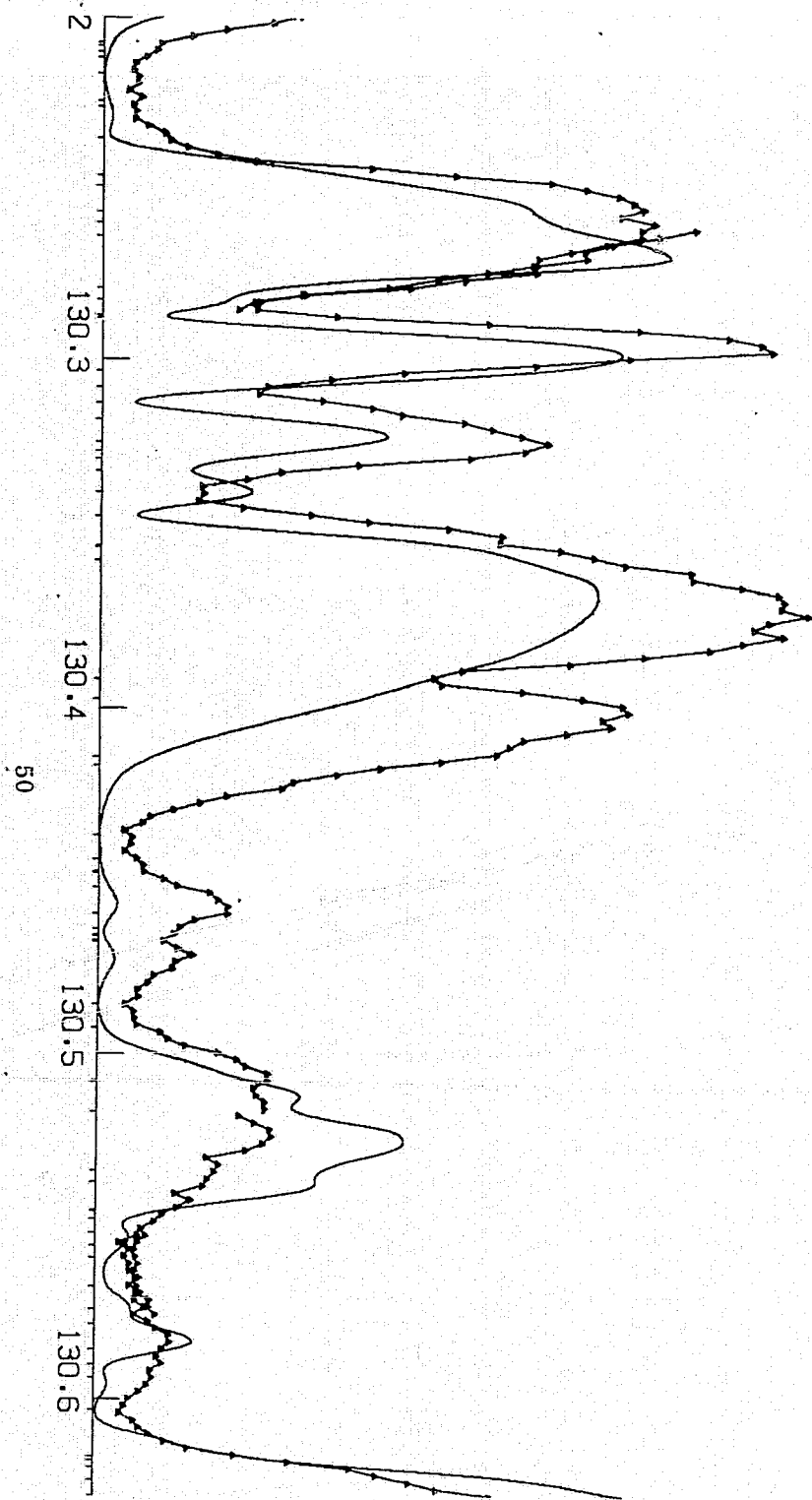
Figure 8 (Continued)

Figure 9. Calculated spectrum for Sirius compared to the observations with identifications. See Figure 8 for an explanation.



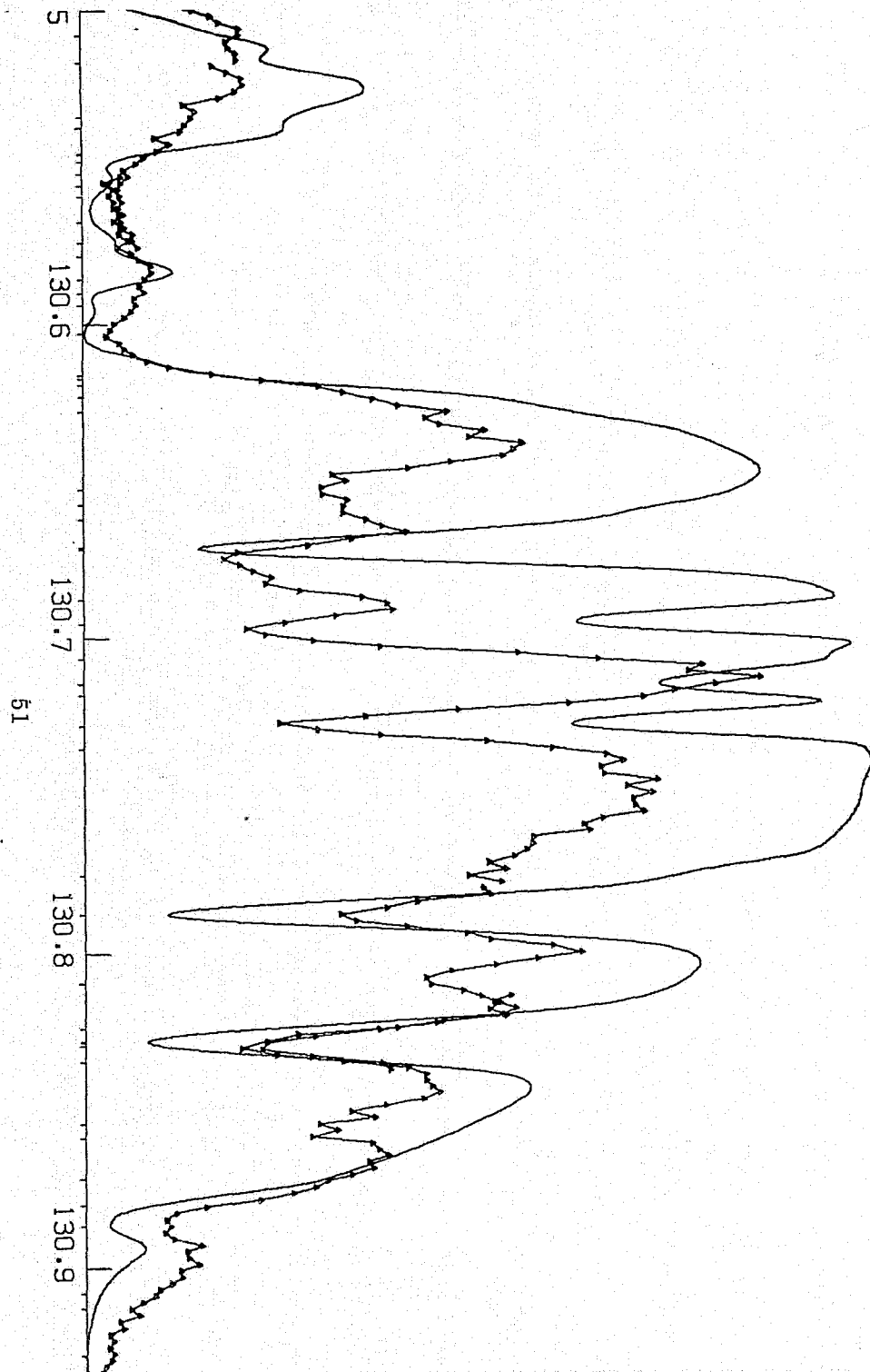
71	23.02	11966	613	22	24.02	20702	480
				52	24.02	17395	778
265	28.01	24788	128	220	28.01	53601	177
				253	23.02	11591	413
567	27.01	3950	12	543	28.01	53037	289
				788	7.01	15316	298
				814	7.01	15316	790
929	26.02	73727	978				
35	7.01	15316	462	21	26.02	93388	794
				268	26.02	70728	820
366	26.01	2430	920				
565	26.02	70725	946				
				866	14.01	76665	105
				55	25.01	29889	22
151	26.01	2430	863	160	14.02	52853	21
562	25.01	29919	834				
595	14.01	76665	165				
				778	25.01	29889	898
859	15.01	0	0	852	26.02	49576	138
				866	28.01	23796	461
75	26.02	85697	617	83	26.02	83237	932
102	25.01	29951	213	118	26.02	93512	475
168	8.00	0	0				
248	28.01	28070	586	283	23.02	11789	890
353	16.00	396	0				
				484	28.01	55018	828
				493	28.01	29593	935
603	28.01	54262	888	572	26.02	63425	578
643	24.02	20851	871				
792	26.01	15844	3	823	24.02	17272	880
877	16.00	396	0	869	26.02	92523	554
31	26.01	53037	933				
80	28.01	52738	334				
123	16.00	396	0				
172	28.01	52738	556	172	28.01	23108	800
237	28.01	55018	850				
285	28.01	57060	903	261	28.01	53601	380
320	14.02	53115	19				

Figure 9 (Continued)



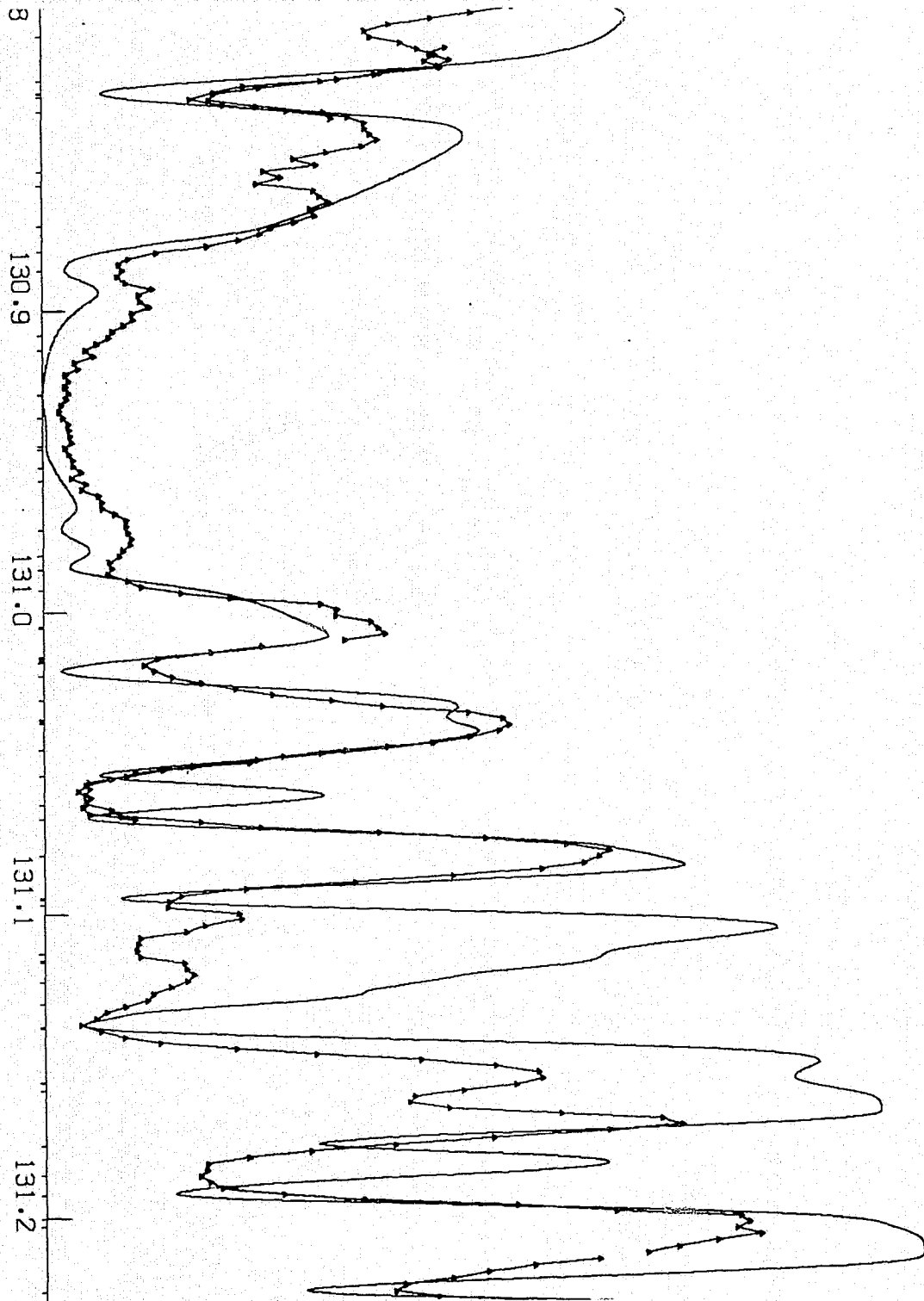
75	26.02	89697	617	89	26.02	83237	932
102	25.01	29951	213	118	26.02	93512	475
168	8.00	0	0				
248	28.01	29070	586	263	23.02	11769	890
353	16.00	396	0				
				464	28.01	55018	828
				493	28.01	29593	935
603	28.01	54262	686	572	26.02	63425	978
643	24.02	20851	871				
792	26.01	15844	3	823	24.02	17272	880
877	16.00	396	0	859	26.02	92523	594
31	28.01	53037	933				
80	28.01	52738	334				
123	16.00	396	0				
172	28.01	52738	555	172	28.01	23108	800
237	28.01	55018	850	261	28.01	53601	380
285	28.01	57080	903				
320	14.02	53115	19	378	26.02	90483	827
448	16.00	0	0				
536	26.02	89783	894	535	30.02	141327	962
				575	26.02	70694	571
914	28.02	61339	811				
				972	29.01	69867	972
165	26.02	70728	568	138	26.02	83358	973
366	14.01	0	0				
437	26.02	90423	964				
471	15.00	0	467	475	15.01	164	0
517	24.02	20702	964				
595	28.01	55018	499				
640	20.01	13650	1	657	28.01	32499	903
658	15.01	164	0	672	28.01	57420	949
677	26.02	62606	549				
				857	8.00	158	0
923	28.01	57420	935				
79	24.02	20994	403	82	28.01	58493	960
				170	28.01	55018	153
				340	28.02	53703	258
				371	25.01	29919	953
455	28.01	53634	785	453	28.01	55018	887
480	15.01	164	0	457	26.02	80483	810
557	29.01	71919	921	520	28.01	29070	927
591	14.01	55325	1				
674	20.01	13710	0	674	20.01	13710	4
				739	25.01	14593	947
				781	26.01	15844	1
				853	26.02	90423	664
				897	16.00	573	0
				937	23.02	28746	276
				28	8.00	226	0
165	25.01	29919	71	174	28.01	52738	950
195	23.02	11768	532				
232	28.01	52738	939				
232	28.01	52738	939				

Figure 9 (Continued)



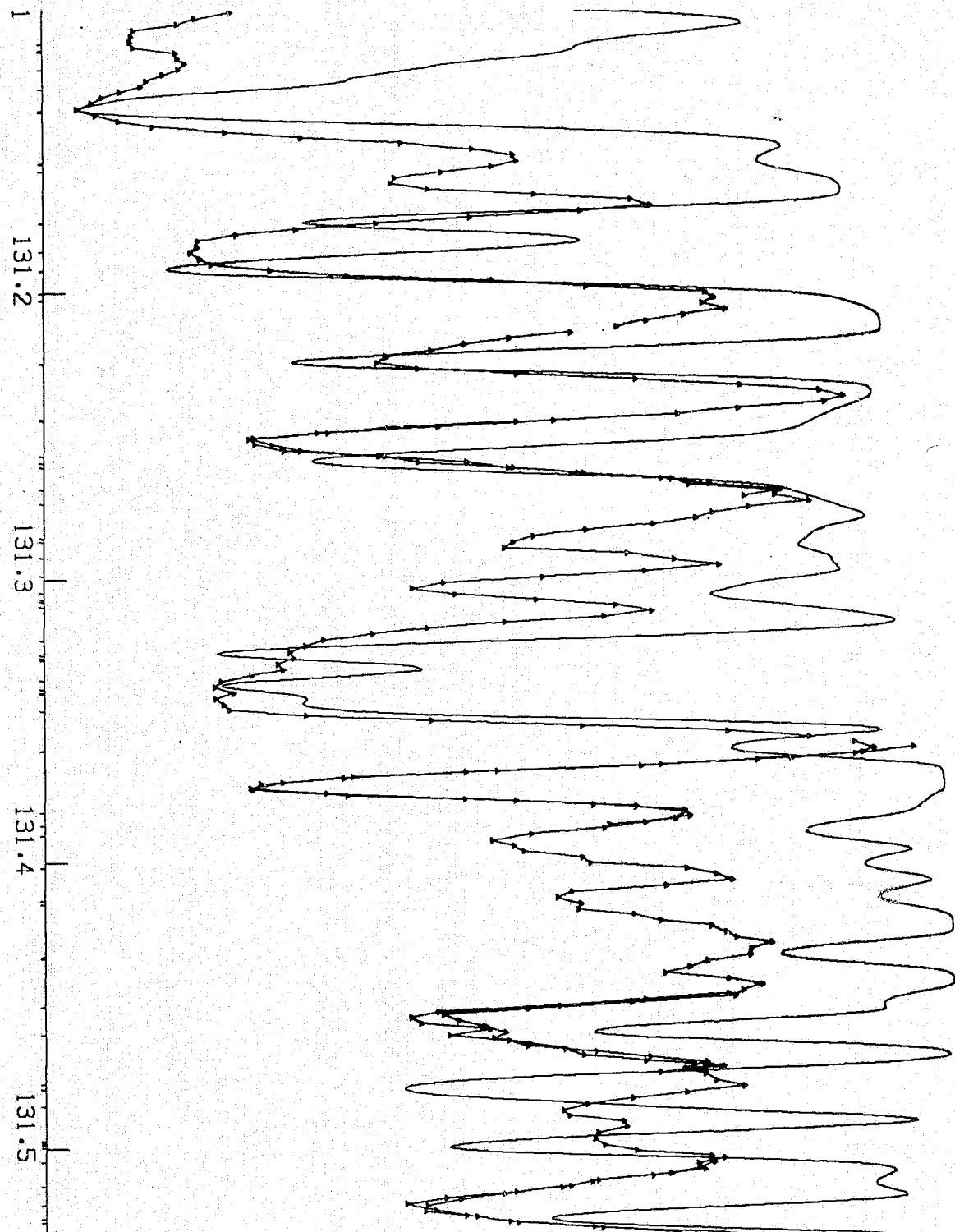
79	24.02	20994	403	82	28.01	58483	980
				170	28.01	55018	153
				340	28.02	53703	258
				371	25.01	29919	953
455	28.01	53634	785	453	28.01	55018	887
480	15.01	164	0	457	26.02	90483	810
557	29.01	71919	921	520	28.01	29070	927
581	14.01	55325	1				
574	20.01	13710	0	674	20.01	13710	4
				738	25.01	14593	947
				781	26.01	15844	1
				853	26.02	90423	664
				897	16.00	573	0
				937	23.02	28746	276
				28	8.00	226	0
165	25.01	29919	71	174	28.01	52738	960
195	23.02	11769	532				
232	28.01	52738	939				
280	28.01	54262	760				
529	28.01	54262	857				
				577	23.02	28746	777
				621	28.01	52738	488
710	25.01	29951	210	714	12.01	35669	5
875	26.02	90483	974				
952	27.01	4026	35				
				63	24.02	20851	768
				145	28.01	54262	275
				180	28.01	53634	903
277	28.01	54262	119				
				350	30.02	137866	958
				748	26.02	70694	684
875	12.01	35669	4				
				93	26.01	2837	971
239	26.02	89783	853				
278	26.02	70725	950	279	12.01	35760	18
281	12.01	35760	4	292	29.01	68447	953
342	26.02	70728	648				
				541	26.02	63425	966
				587	24.02	20702	978
716	28.01	58705	954				
801	26.01	2837	5				
				866	28.01	0	0
79	28.01	57420	874				
126	28.01	53501	911				
273	14.01	287	0				

Figure 9 (Continued)



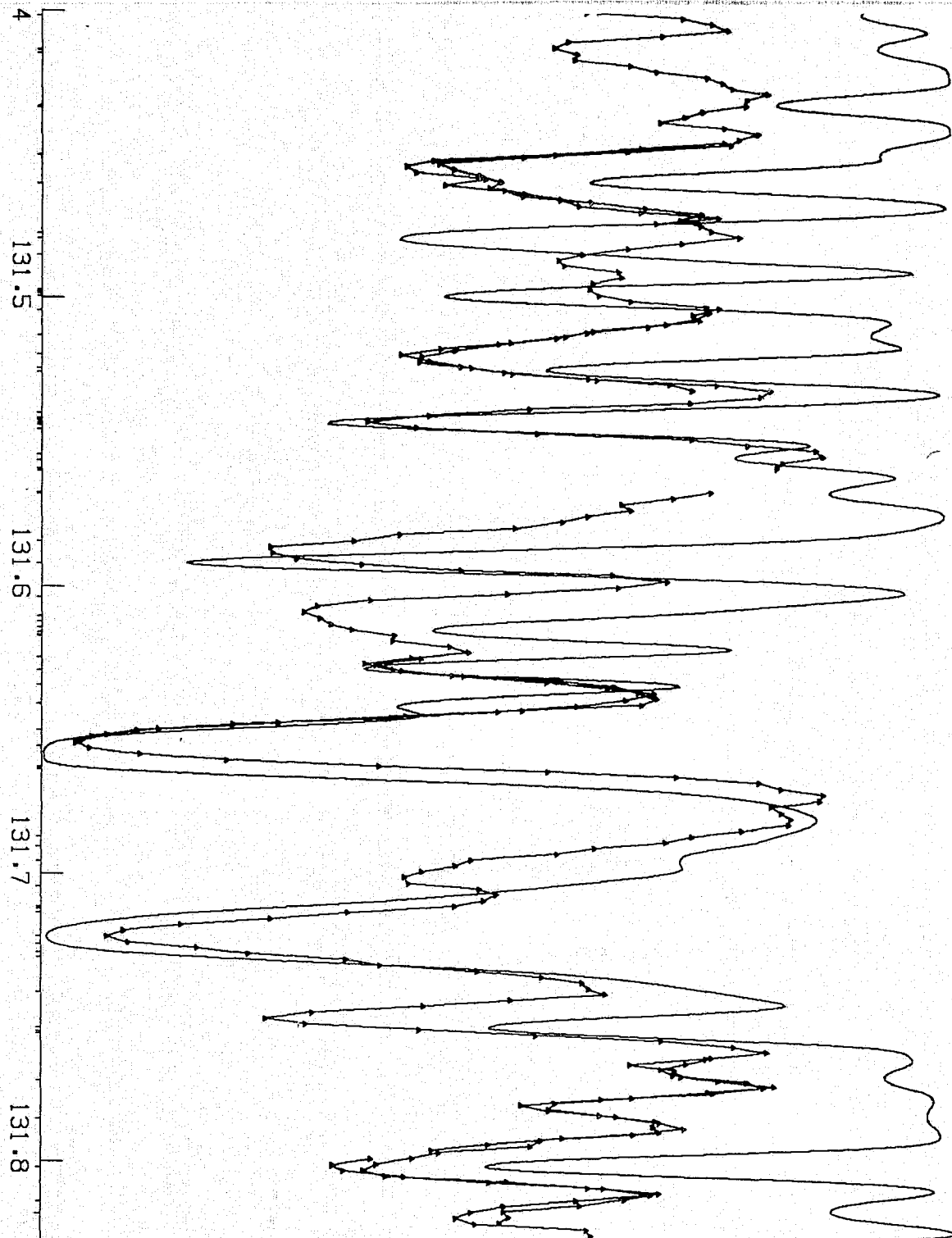
	93	26.01	2837	971			
239	26.02	89783	853				
278	26.02	70725	960				
281	12.01	35760	4	279	12.01	35760	18
342	26.02	70728	648	292	29.01	68447	953
				541	26.02	63425	965
				587	24.02	20702	978
716	28.01	58705	954				
801	26.01	2837	5				
				866	28.01	0	0
79	28.01	57420	874				
126	28.01	53601	911				
273	14.01	287	0				
350	24.02	25725	125				
443	12.01	35780	3	453	14.01	55309	2
516	24.02	20994	694				
558	23.02	11966	773				
724	14.01	55325	6				
809	26.02	82382	638				
923	26.02	63486	951	857	15.01	469	0
45	26.02	63494	970	51	28.01	55417	908
155	6.00	10192	182	148	26.01	15844	964
166	26.01	16369	174	161	25.01	33147	974
				212	16.00	396	0
357	28.01	57420	904	291	26.02	82410	932
370	26.02	89907	607	361	28.01	57420	758
				370	26.02	89907	810
				457	28.01	51557	216
				541	7.00	28839	1
637	6.00	10192	605				
685	15.01	469	0				
804	23.02	11591	806				
950	7.00	28839	3	944	7.00	28838	1
				966	26.02	89907	695
126	27.01	4028	439	149	24.02	20851	804
153	28.01	55417	691	219	26.01	1872	9
288	26.01	2430	6				
363	6.00	10192	1	369	26.02	92523	718
548	24.02	20851	864	546	28.02	62606	830
				574	28.01	54557	976
758	26.01	16369	2				
924	6.00	10192	2	856	27.01	4560	109
2	24.02	20702	943				
				26	24.02	18581	917
247	6.00	10192	5				

Figure 9 (Continued)



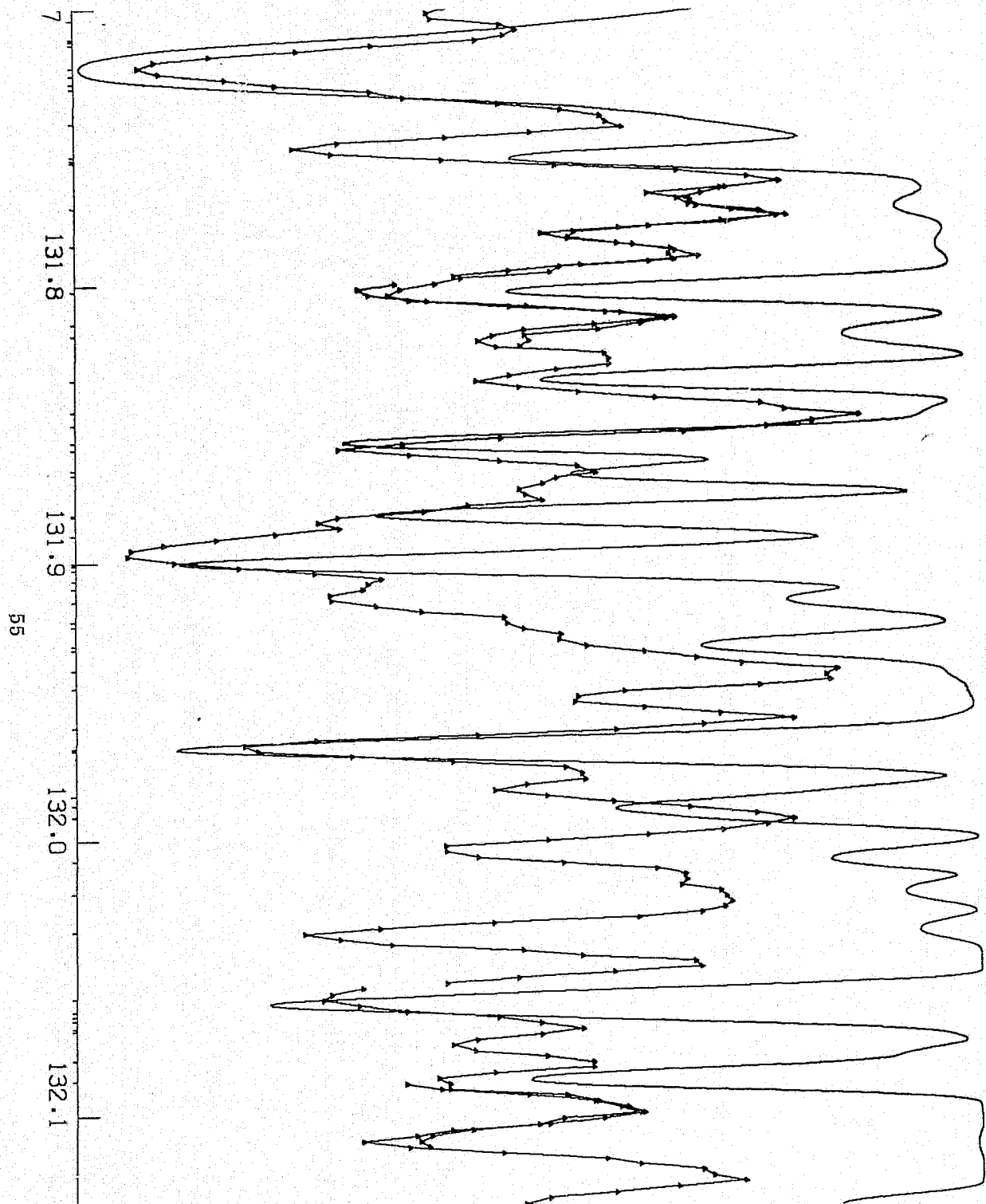
126 27.01	4028 439	149 24.02	20851 804
153 28.01	55417 691	219 26.01	1872 9
288 26.01	2430 6		
363 6.00	10192 1	369 26.02	92523 718
548 24.02	20851 864	545 28.02	62606 830
		574 28.01	54557 576
758 26.01	16369 2		
824 6.00	10192 2	856 27.01	4580 109
2 24.02	20702 543	28 24.02	18801 817
247 6.00	10182 5		
440 28.01	54557 921	445 26.02	63488 848
569 26.02	63494 898		
581 14.02	82884 131	806 23.01	36 875
683 26.02	82382 958	734 23.01	208 838
735 28.01	58493 944		
866 7.00	28839 935	855 6.00	10192 789
921 26.02	70725 760		
45 26.02	63466 549	986 26.02	70728 785
71 7.00	28838 955		
96 26.02	89783 726	78 7.00	28839 965
277 7.00	28838 965	217 28.01	58493 973
		267 16.00	573 0
354 23.02	12187 114	283 7.00	28839 965
398 26.02	63486 790	387 6.00	10192 45
		403 28.01	53365 439
		464 6.00	10192 11
607 26.01	3117 247		
		823 23.01	106 906
		858 23.02	11769 927
		903 28.01	53365 581
		17 24.02	20994 716
144 29.01	70841 979	131 26.02	49576 784
333 28.01	68730 926	332 26.02	83425 591
		504 26.02	80423 781
801 26.02	40989 236		
788 26.01	16369 29	771 28.01	53365 181
846 28.01	53365 174		
879 7.00	28839 965	874 7.00	28839 965
995 15.00	0 6	983 23.01	339 771
		45 26.02	63466 743
129 26.02	63425 752		
193 26.02	82382 950		
242 26.02	89907 846	242 26.02	89907 795
255 28.01	53365 98		

Figure 9 (Continued)



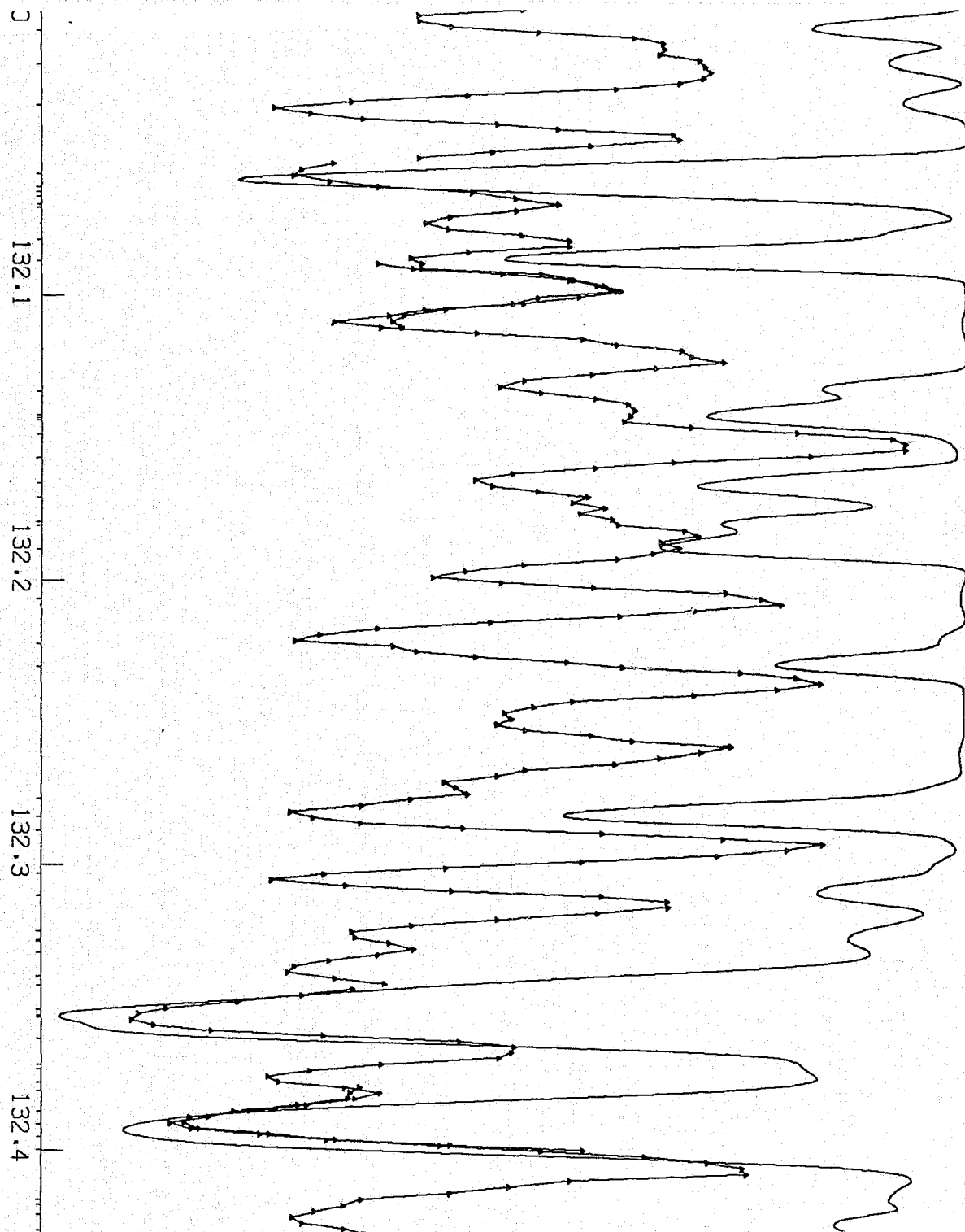
			17 24.02	20994 716
144 29.01	70841 979	131 26.02	49576 784	
333 29.01	68730 928	332 26.02	63425 531	
		504 28.02	90423 791	
601 26.02	40999 236			
789 26.01	16369 29	771 28.01	53365 191	
848 28.01	53365 174			
979 7.00	28839 965	974 7.00	28839 965	
995 15.00	0 6	983 23.01	339 771	
		45 26.02	63466 743	
129 26.02	63425 752			
193 26.02	82382 950			
242 26.02	89907 846	242 26.02	89907 795	
255 28.01	53365 98			
397 26.02	63486 952	414 26.02	89697 845	
419 27.01	4950 273	430 7.00	28839 55	
436 7.00	28839 75	452 24.02	25725 421	
		540 26.02	90483 674	
559 28.01	55018 643	597 24.02	20702 969	
590 23.01	208 854	679 26.02	82410 692	
673 28.01	53496 929			
842 26.02	63466 845			
918 6.00	10192 2			
36 7.00	28839 965			
120 25.02	68899 861	101 27.01	4560 351	
157 25.01	38366 942	139 25.01	38366 965	
169 25.01	38366 948	166 26.02	50412 157	
246 28.01	54262 957			
		291 7.00	28839 15	
		344 26.01	8391 977	
408 24.02	25781 154			
557 16.00	0 0	501 28.01	54176 674	
637 16.00	0 1	628 16.00	0 0	
		869 26.02	40999 875	
		905 26.02	89783 854	
955 28.01	53365 544			
45 28.01	53496 518			
114 28.01	55018 819	122 28.01	53496 474	
134 26.02	82494 931	217 28.01	0 0	
244 26.01	7955 940	290 26.01	7955 352	
271 23.02	11966 141			
409 28.01	53365 862			
545 26.01	20340 938	531 28.01	53496 154	
		552 26.02	40999 460	
717 26.02	93388 865			
		851 28.02	62606 953	
		19 28.01	53496 49	
		136 24.02	18510 967	
		180 27.01	5204 522	

Figure 9 (Continued)



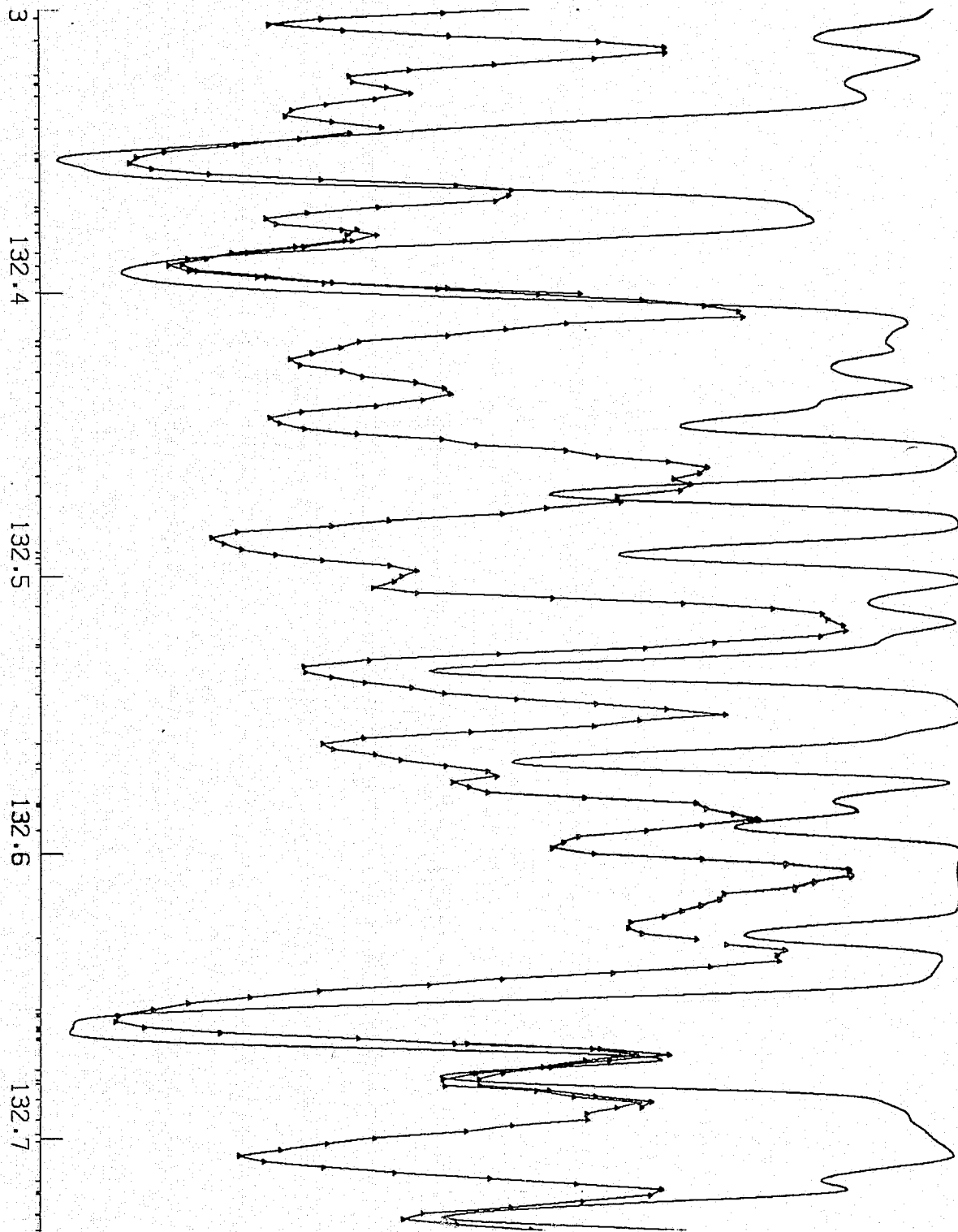
45	28.01	53496	518		
114	28.01	55018	819	122	28.01
134	26.02	82494	931		53496 474
244	26.01	7955	940	217	28.01
271	23.02	11966	141		0 0
				290	26.01
409	28.01	53365	862		7955 352
545	26.01	20340	938	531	28.01
				552	26.02
717	26.02	93388	865		53496 154
					40999 480
				851	28.02
					82606 953
				18	28.01
					53496 48
				136	24.02
				180	27.01
					18510 987
					8204 522
				339	28.01
					2837 7
				454	26.02
				501	7.00
564	26.01	20516	3	588	27.01
					4950 388
680	15.00	0	22	665	25.01
					38542 907
823	7.00	28838	9	830	7.00
				899	28.01
					24788 567
999	7.00	28838	2	6	7.00
25	15.00	0	26	64	26.02
				92	30.02
				141	26.02
					28839 4
					89907 959
					140654 820
					49148 512
228	25.01	38542	972	211	25.01
					38542 927
310	28.01	55018	503	296	26.02
					73727 509
447	26.02	42896	967	381	24.02
					18581 893
592	28.02	63472	806		
677	7.00	28838	2	670	7.00
					28838 3
838	27.01	5204	523		
871	26.02	93512	676		
911	26.01	20516	202	914	26.02
					82494 753
71	24.02	43286	568		
192	28.01	55018	740		
334	27.01	4560	949	331	26.02
					90483 844
639	28.01	56075	897	577	26.01
681	29.01	70841	932	623	26.01
				655	26.01
				692	24.02
					3117 5
					20340 11
					16359 960
					25725 954
798	28.01	55018	712		
874	26.01	2430	5		

Figure 9 (Continued)



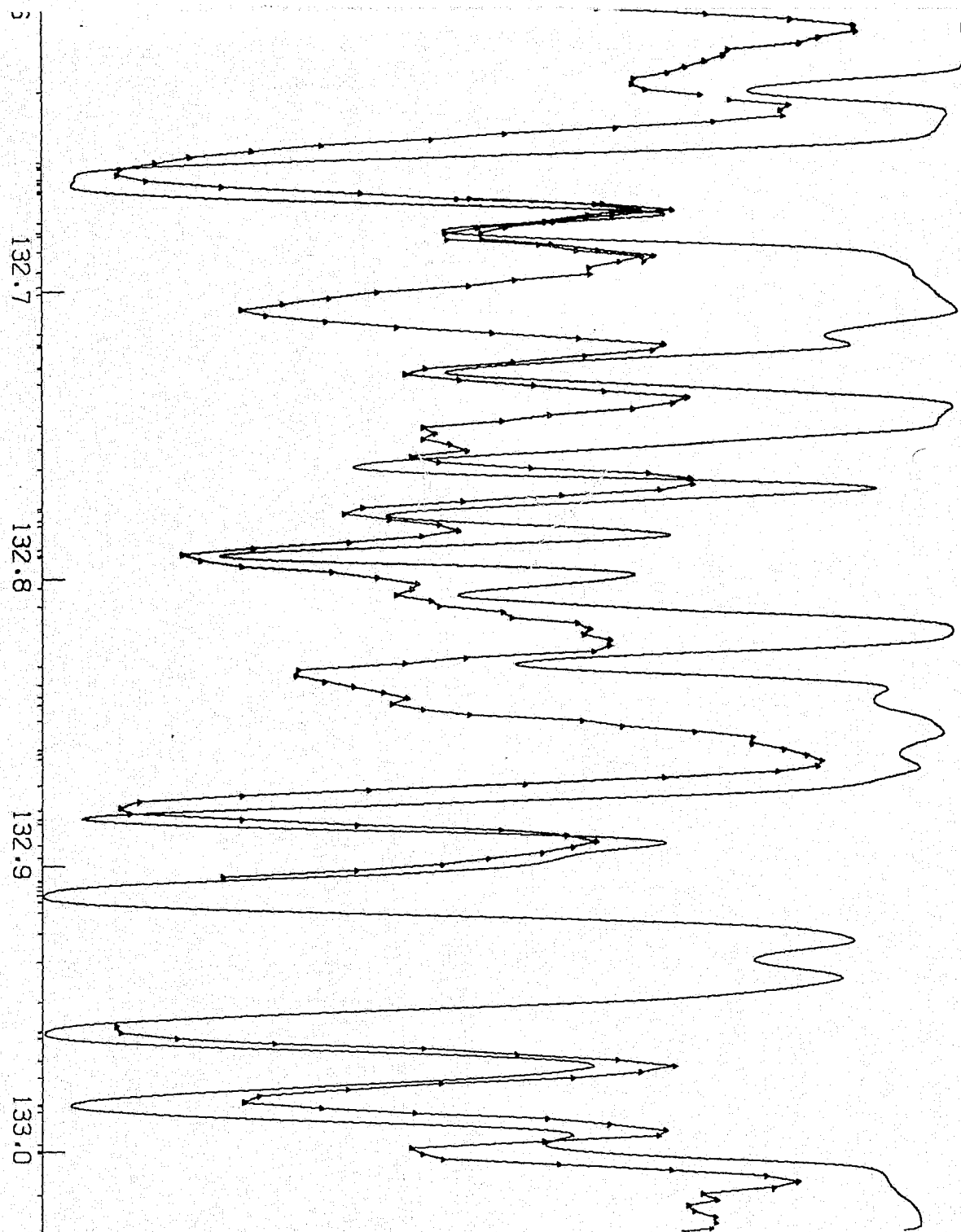
71	24.02	43286	568				
192	28.01	55018	740				
334	27.01	4560	949	331	26.02	90483	844
638	28.01	56075	897	577	26.01	3117	5
681	29.01	70841	932	623	26.01	20340	11
				655	26.01	16369	960
				692	24.02	25725	954
798	28.01	55018	712				
874	26.01	2430	5				
				332	28.02	61339	622
425	15.00	0	677	414	26.02	73849	639
482	28.01	55018	904	432	28.01	56075	644
563	26.02	84369	980				
				655	24.02	25781	428
				704	28.01	53634	601
791	29.01	70841	965	804	28.02	54657	443
889	26.01	2837	76				
				65	23.01	208	979
				221	25.02	68892	916
				304	28.02	61339	530
767	26.02	82382	861				
830	24.02	25848	193	828	28.01	56075	675
877	27.01	4950	906				
				28	27.01	5204	910
				107	28.01	54262	575
230	28.01	25036	919	258	26.02	82410	869
264	25.01	38806	945	304	26.02	83161	971
				387	26.02	57221	956
				419	28.01	56075	282
521	16.00	395	0	501	30.02	142483	963
605	26.01	20805	5	530	16.00	395	0
711	28.01	56075	979	696	26.02	42896	865
758	25.01	38806	832	789	29.01	73101	977
				862	6.01	74932	212
				906	6.01	74932	58
951	6.01	74930	43				
996	6.01	74930	212				
167	24.02	18510	875	183	25.01	34910	955
				218	28.01	55299	928

Figure 9 (Continued)



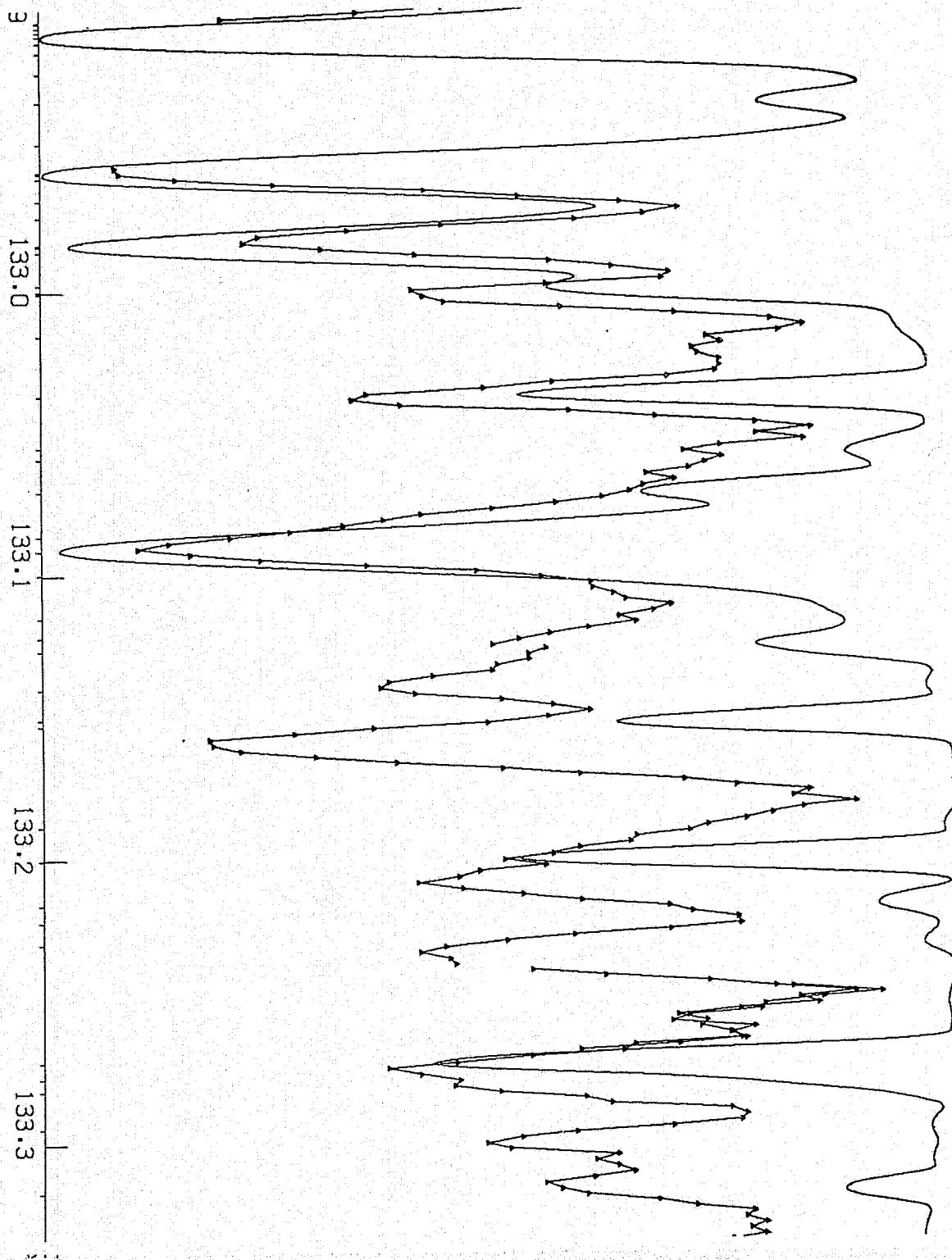
				28 27.01	5204 910
				107 28.01	54262 575
230 28.01	25036 919	258 26.02	82410 869		
264 25.01	38806 945	304 26.02	83181 971		
		387 26.02	57221 956		
		419 28.01	58075 282		
521 16.00	395 0	501 30.02	142483 963		
605 26.01	20805 5	530 16.00	395 0		
711 28.01	58075 979	696 26.02	42896 665		
758 25.01	39806 832	789 29.01	73101 977		
		862 6.01	74932 212		
951 6.01	74930 43	906 6.01	74932 58		
996 6.01	74930 212				
167 24.02	18510 875	183 25.01	34910 955		
273 26.01	8846 551	218 26.01	55299 928		
395 28.02	63472 644	347 23.01	339 952		
474 28.01	55299 244				
843 26.02	83237 936				
715 26.02	50184 208				
912 26.01	8391 607	932 26.02	40999 377		
951 25.01	14325 819				
		107 28.01	55299 685		
243 28.01	55299 751	251 29.01	73101 977		
327 26.02	50184 431				
357 28.01	55299 81	423 24.02	18581 970		
601 26.02	57221 787				
675 26.01	20805 13	692 28.01	29070 882		
823 28.01	58371 918	818 28.02	62606 693		
817 26.02	40599 428	830 26.02	83138 838		
		294 28.01	55417 371		
585 7.00	28838 9	550 28.01	55417 306		
608 26.02	40999 644	571 7.00	28839 3		
624 28.01	56371 434	619 28.02	63472 751		
649 16.00	573 0	647 26.02	49576 735		
		654 26.02	50295 698		
757 28.01	56424 966				
792 26.01	3117 5	805 27.02	55729 960		
		858 26.02	84671 818		
		931 26.02	50276 885		
9 23.02	12187 965	985 14.02	159069 972		
191 28.01	58705 893	147 26.02	42896 684		
267 26.02	50295 200	185 28.01	55417 921		
322 28.01	55417 971	263 26.02	57221 425		

Figure 9 (Continued)



				294	28.01	55417	371
565	7.00	28836	9	550	28.01	55417	306
566	26.02	40399	644	571	7.00	28839	3
574	28.01	56371	434	619	28.02	63472	751
649	16.00	573	0	647	26.02	49576	735
				654	26.02	50295	698
757	28.01	56424	966				
792	26.01	3117	5	805	27.02	55729	960
				858	26.02	84671	818
				931	26.02	50276	885
9	23.02	12187	965	985	14.02	159089	972
191	28.01	59705	893	147	26.02	42896	684
267	26.02	50295	200	185	28.01	55417	921
322	28.01	55417	271	263	26.02	57221	425
				465	25.01	38366	917
				545	26.02	49576	357
				514	22.02	8472	11
754	28.01	56371	164	764	24.02	18451	889
797	28.01	55417	781	797	26.01	2430	210
813	24.02	43286	405				
918	7.00	28836	4	900	23.02	27727	436
				924	7.00	28839	7
				28	26.01	2837	18
				92	28.02	54657	308
				302	14.01	75665	175
367	30.02	141327	908				
408	29.01	73353	932	491	26.02	82410	941
436	24.02	43321	799				
				510	26.02	42896	895
595	26.02	93512	971				
627	28.01	56371	967				
718	26.02	50412	866				
805	24.02	18510	961				
834	6.00	0	0	849	28.01	52738	608
923	28.01	58705	945				
968	28.01	56424	248				
49	28.01	58493	945	51	23.02	16810	659
84	6.00	16	0	100	6.00	16	0
123	6.00	16	0	70	28.01	54262	411
121	26.02	85847	658	158	26.02	50483	926
233	28.01	56424	961				
				333	26.02	50412	61*
477	28.01	55018	858				
600	6.00	43	0	577	6.00	43	0
678	29.01	73353	975	581	28.01	54262	444
				738	28.02	82172	879
833	22.02	0	52	836	26.02	63494	974
898	28.01	13650	0	839	28.01	58705	864
859	28.01	56424	408				
996	26.01	8680	387	974	25.02	82494	891
				5	26.02	73727	546
151	26.02	83237	973				

Figure 9 (Continued)



49	28.01	58493	945	51	23.02	16810	858
124	6.00	16	0	100	6.00	16	0
123	6.00	16	0	70	28.01	54282	411
121	26.02	86847	958	158	26.02	80483	826
233	28.01	56424	961				
				333	26.02	50412	614
477	28.01	55018	858				
500	6.00	43	0	577	6.00	43	0
581	28.01	54262	444				
678	29.01	73353	975	738	28.02	82172	879
833	22.02	0	52	836	26.02	63494	974
838	20.01	13650	0	839	28.01	58705	864
859	28.01	56424	408	974	26.02	82494	881
995	26.01	6680	387	5	26.02	73727	546
151	26.02	83237	973				
363	26.02	50276	194				
590	25.01	38542	889	549	28.01	54262	822
				701	26.02	50295	445
912	20.01	13710	0	859	25.01	14325	975
997	26.02	69836	976	912	20.01	13710	4
				149	26.02	84369	903
402	28.02	86646	954	218	24.02	43304	788
				266	28.01	55018	560
				506	25.01	14325	387
				530	24.02	43321	441
884	29.01	71493	960				
2	23.02	16977	101				
157	26.02	73849	772	216	29.01	71493	939
				295	26.02	83358	901
712	26.01	18360	8				
765	23.02	12187	928	767	28.01	54262	510
				812	28.01	58705	790
				945	28.01	54262	954
				172	28.01	54262	678

Figure 9 (Continued)

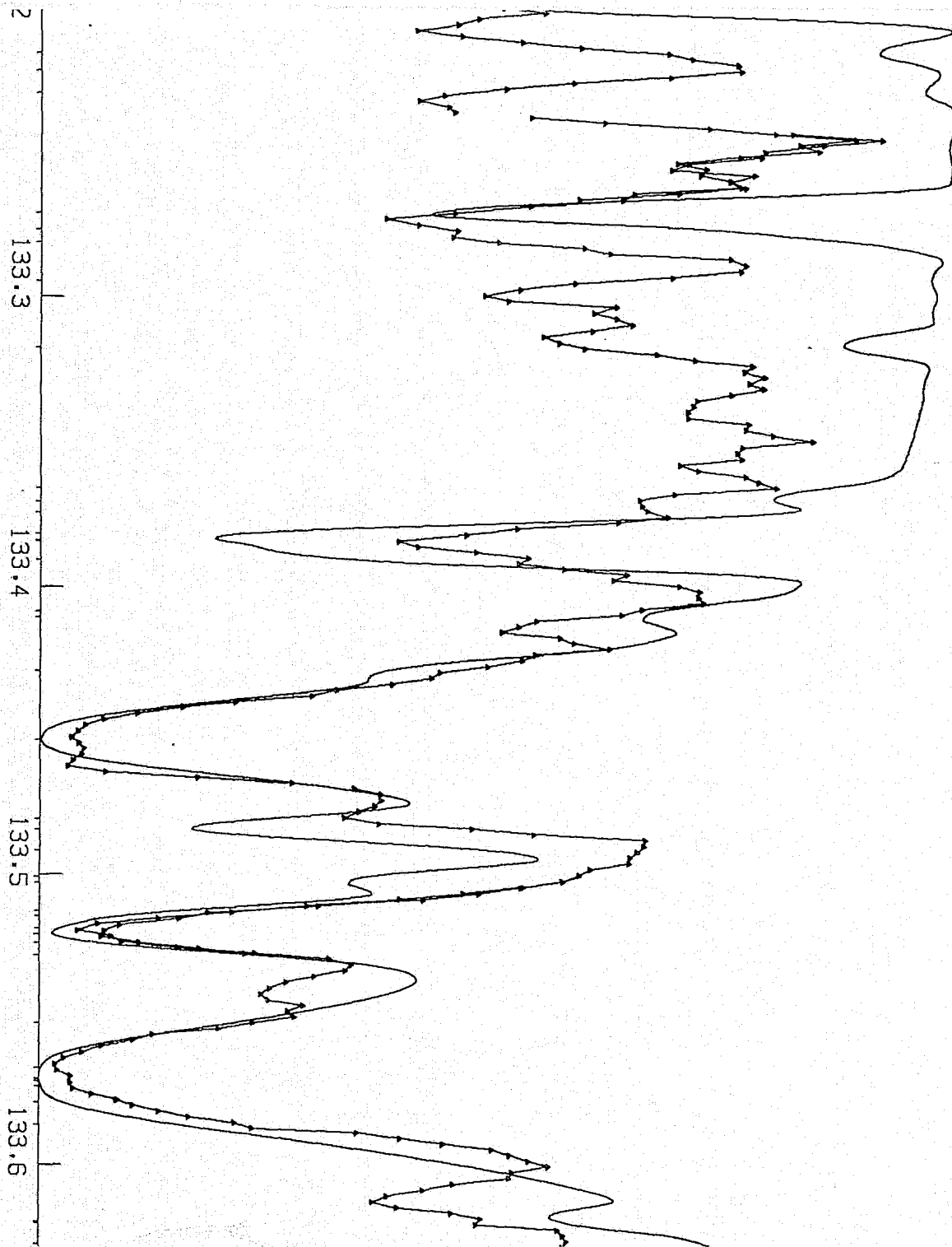
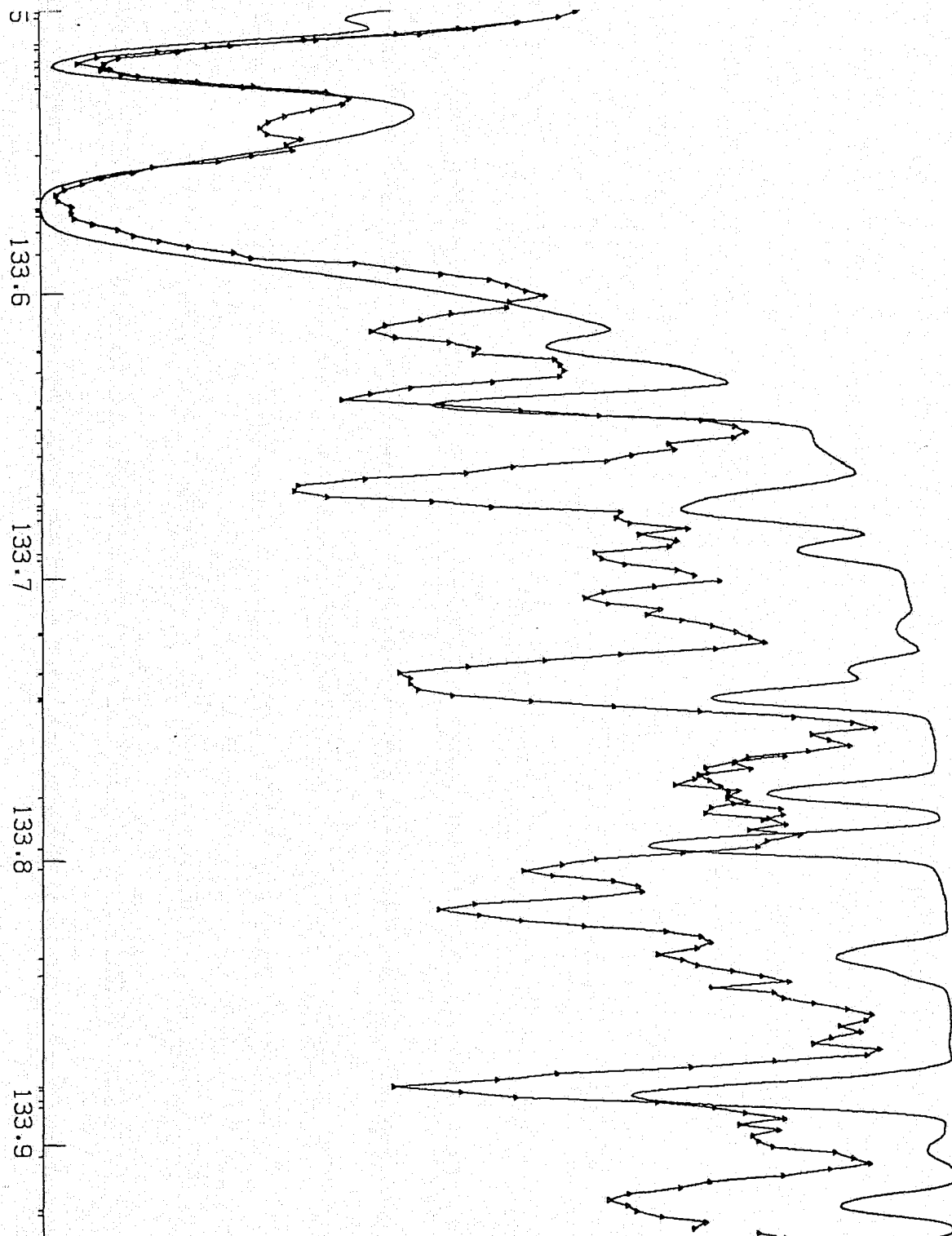


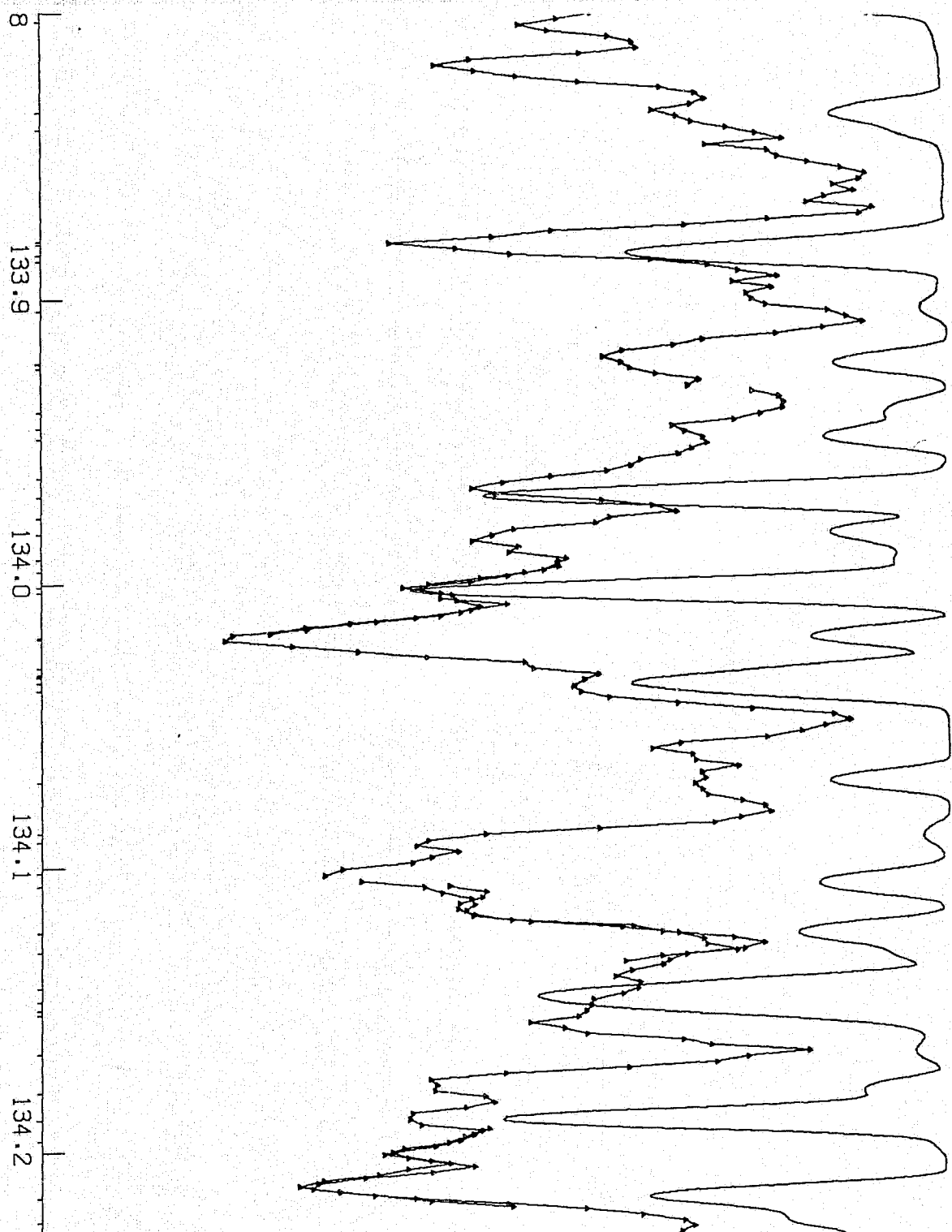
Figure 9 (Continued)

157	26.02	73849	772				
				216	29.01	71493	939
				295	26.02	83358	901
712	26.01	18360	8				
766	23.02	12187	928	767	28.01	54262	510
				812	28.01	58705	790
				945	28.01	54262	954
				172	28.01	54262	678
				653	28.02	82172	934
				701	26.02	73935	666
				739	25.01	14593	931
836	23.02	11966	972	814	15.00	0	4
				839	26.01	21308	12
				903	26.01	18360	5
84	28.02	82277	919	103	28.01	56075	574
				291	28.01	54557	252
				532	6.01	0	0
807	28.01	54557	955				
844	15.02	0	47				
917	28.02	55952	748				
7	28.02	55406	799	27	26.01	2837	30
122	23.02	16810	117	140	26.02	83358	990
201	28.01	1506	0	182	7.00	28839	823
231	26.02	70725	573				
273	25.01	38806	664				
				508	28.02	82277	855
701	28.01	56075	758	663	6.01	63	0
726	17.00	0	0	708	6.01	63	0
				702	28.01	54557	108
				782	28.01	54557	260
				659	26.02	57221	920
196	26.02	63425	625	202	28.01	54557	469
773	26.01	14593	773				



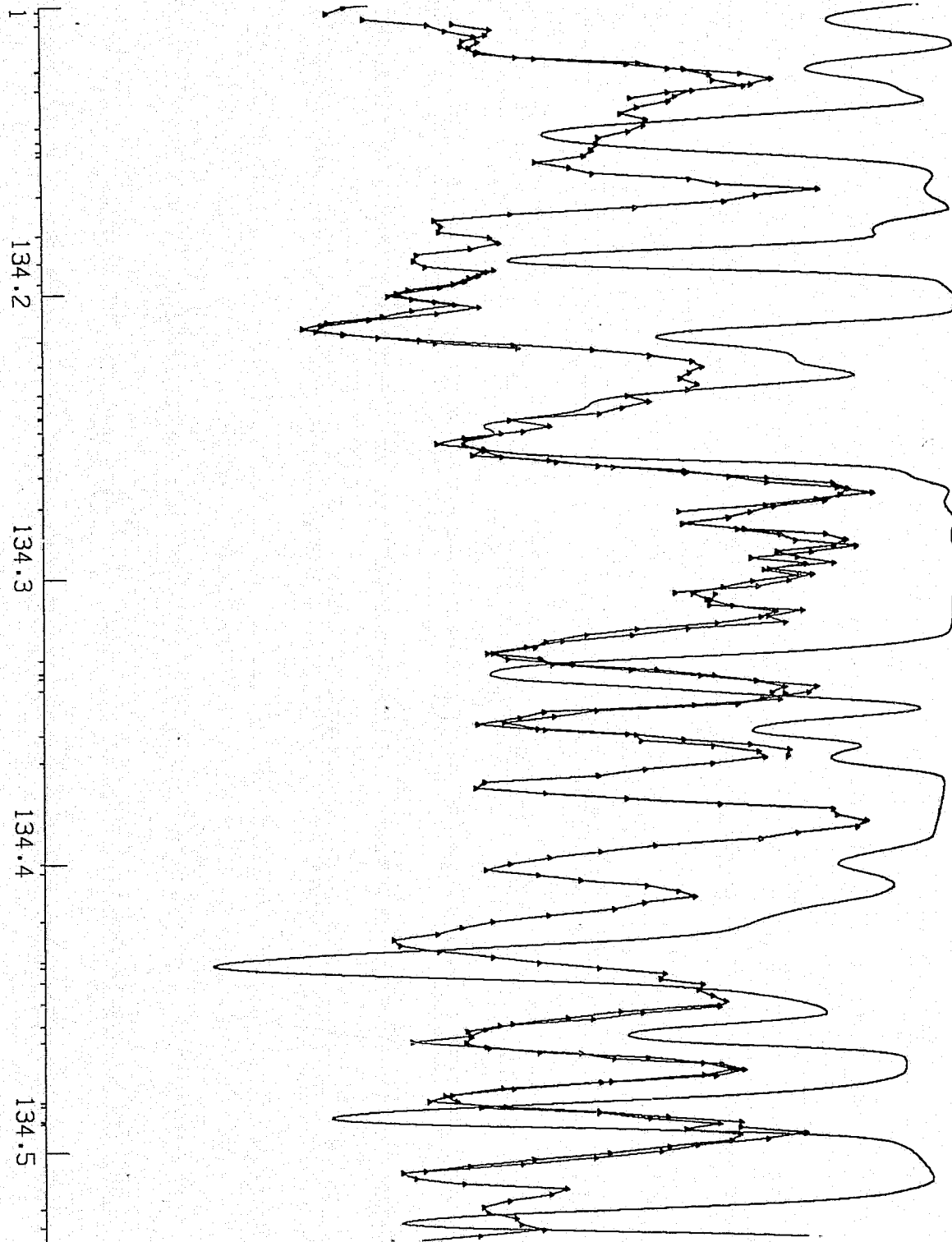
122	23.02	16810	117	140	25.02	83358	980
201	28.01	1506	0	182	7.00	28839	823
231	25.02	70725	573				
273	25.01	38806	864				
				508	28.02	82277	855
701	28.01	56075	758	663	6.01	83	0
726	17.00	0	0	708	6.01	63	0
				702	28.01	54557	108
				782	28.01	54557	280
				859	28.02	57221	920
196	26.02	63425	625	202	28.01	54557	489
273	25.01	14593	773				
394	7.00	28838	667	401	7.00	28839	91
476	28.01	55018	978				
521	26.02	84671	948				
569	28.01	55417	936				
760	28.01	25036	908	708	26.01	21251	714
793	26.02	73849	613	743	26.01	21430	567
911	28.02	82172	713	933	26.02	63466	933
191	7.00	28838	964	199	7.00	28839	964
338	26.01	21581	788	333	26.02	92523	882
429	26.02	83646	966	422	25.01	14325	944
				435	26.02	50184	446
				773	24.02	43304	512
956	28.01	54557	306	960	28.01	56075	455
30	25.01	14325	975				
407	28.01	57080	823	347	26.02	50184	651
797	26.02	63494	778	807	26.02	63494	844
843	28.01	23108	242	857	28.01	56075	651
38	28.02	82172	916				
241	26.02	50184	915	223	28.01	57080	873

Figure 9 (Continued)



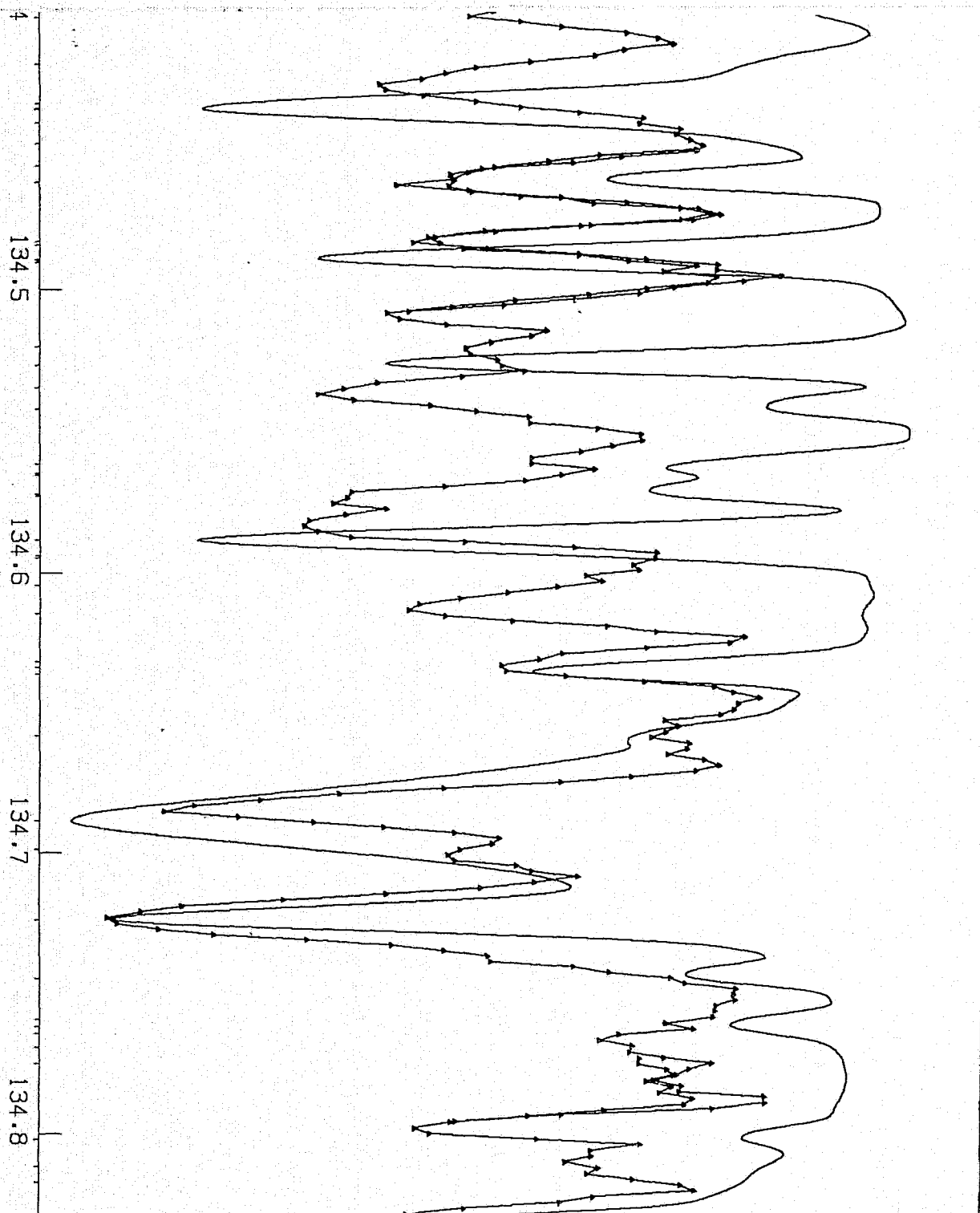
30 25.01	14325 975		
407 28.01	57080 823	347 26.02	50184 691
797 26.02	63494 778	807 26.02	63494 844
843 28.01	23108 242	857 28.01	58075 651
38 28.02	82172 916		
241 26.02	50184 915	223 28.01	57080 673
395 28.01	56371 794		
490 28.01	58075 609	451 26.01	21581 941
		628 25.01	14781 961
767 29.01	71919 953	693 22.02	8472 49
912 26.01	21430 782	823 26.02	63466 663
954 26.02	63425 973		
9 28.01	53365 546	28 26.01	3117 6
194 28.01	56075 797	189 26.02	63485 692
319 26.02	63494 927	296 25.02	63646 848
347 28.01	56424 958	326 26.02	50295 581
		375 28.01	57080 311
		695 26.02	63466 657
879 26.02	50276 949	909 29.01	71919 961
62 26.01	21711 632	16 26.02	84159 950
		61 26.02	63486 841
226 28.01	32523 946	223 26.02	50295 603
		295 28.02	56308 639
470 14.02	142944 450	421 28.02	55406 433
515 26.02	50412 917	500 14.02	142946 635
		654 26.02	77102 923
792 26.01	21711 667		
961 28.01	56424 948	890 20.01	0 6
161 28.02	55406 358		
247 28.01	53365 505		

Figure 9 (Continued)



62 26.01	21711 632	16 26.02	84159 950
		61 26.02	63486 841
226 28.01	32523 946	223 26.02	50295 603
		295 28.02	56308 839
470 14.02	142944 450	421 28.02	55406 433
515 26.02	50412 917	500 14.02	142946 635
		654 26.02	77102 923
792 26.01	21711 667		
961 28.01	56424 948	890 20.01	0 6
161 28.02	55406 358		
247 28.01	53365 505		
		349 14.02	142944 638
430 14.02	142948 541	389 14.02	142946 458
478 26.02	57221 217	433 26.02	50412 688
551 25.01	14593 598	554 20.01	0 7
633 26.01	21581 808		
		746 26.02	113635 967
283 28.01	56371 682		
330 26.01	18885 178	332 26.02	50412 316
346 30.02	145243 973	390 14.02	142946 642
390 14.02	142948 539		
546 14.02	175336 980	546 28.01	56371 406
844 28.01	55417 603		
997 26.02	49148 820	29 26.02	84159 826
197 28.01	56371 765		
353 25.01	32787 61	337 28.01	56371 853
407 28.01	25036 898	357 15.02	559 39
482 26.02	113635 976		
561 24.02	25725 907	617 28.01	53496 202
836 28.02	62606 839	825 28.01	56371 857
890 15.02	559 107	899 15.02	173813 974
197 26.02	63425 818		
		262 26.01	18360 4

Figure 9 (Continued)

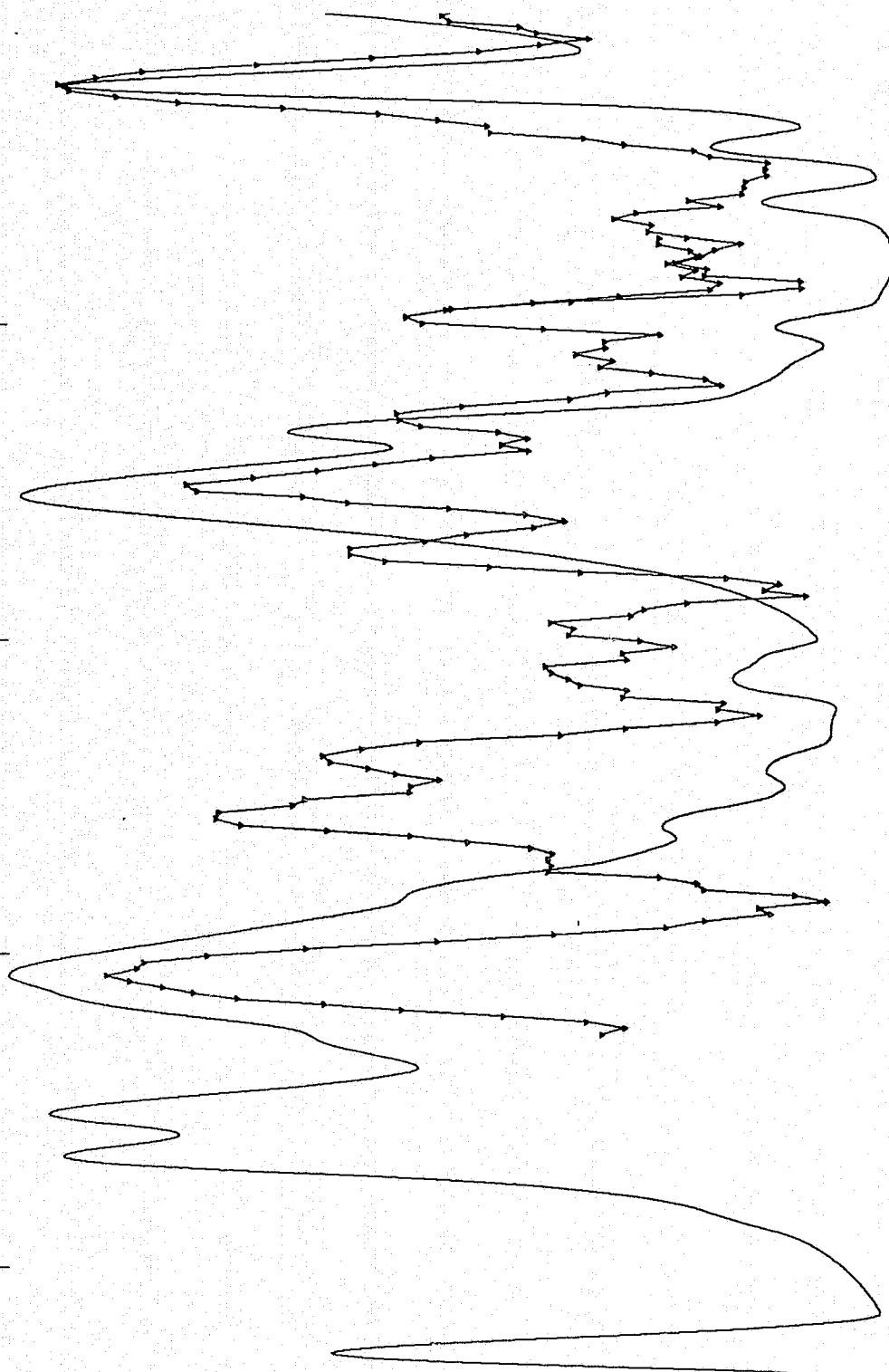


197	28.01	56371	765				
353	25.01	32787	61	337	28.01	56371	863
407	28.01	25036	898	357	15.02	559	39
482	26.02	113635	976				
561	24.02	25725	907				
				617	28.01	53496	202
836	28.02	62606	839	825	28.01	56371	857
890	15.02	559	107	899	15.02	173813	974
197	26.02	63425	818				
				262	26.01	18360	4
				341	28.01	57420	879
				416	28.01	23796	433
608	25.01	32856	394				
642	25.01	32858	854	649	26.02	70725	716
716	26.02	70728	406	723	24.02	20994	972
878	28.01	0	0				
944	26.02	63466	636	937	25.01	14781	720
42	18.01	144709	977				
				142	28.01	56424	956
313	26.02	63496	909	334	28.01	55018	747
358	26.02	70594	310				
				578	25.02	68899	629
884	14.01	42932	2				
				987	26.02	70728	693
240	17.00	0	0				
446	23.02	28746	522				
593	28.02	62606	954	618	25.02	68892	667
644	28.01	55299	885	691	28.02	83033	944
				749	25.02	68899	977
				19	26.02	87901	705
114	25.01	14901	916				
				170	28.01	55299	951

Figure 9 (Continued)

7
134.8
134.9
135.0
135.1

65



240	17.00	0	0
446	23.02	28745	522
593	28.02	62605	954
644	28.01	55299	865
618	25.02	68892	667
691	28.02	83033	944
749	25.02	68899	977
19	26.02	87901	705
114	25.01	14901	916
170	28.01	55299	951
335	28.01	23108	13
418	28.01	56075	941
543	14.01	42824	2
629	14.02	176487	958
703	28.02	82826	959
751	18.01	132481	923
84	28.01	55299	692
158	26.02	49576	742
143	28.02	83033	830
165	28.01	55299	929
264	26.02	70728	973
415	25.01	32787	798
583	28.01	55299	812
582	28.01	32523	823
783	28.01	55417	413
72	14.01	43107	1
137	26.02	63494	637
176	13.01	59849	51
229	26.02	63466	882
258	28.01	56075	690
286	25.01	14781	820
321	28.01	55417	405
438	26.02	63494	721
486	26.02	84359	952
516	14.01	42932	3
428	26.02	63494	485
570	26.02	83646	935
556	14.01	42824	4
868	28.02	82826	916
864	24.02	57422	976
249	28.02	55952	421
288	28.01	23796	25
317	28.02	55952	735

Figure 9 (Continued)